forum

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The Editorial objective is to report developments and advanced techniques of particular interest to the professional aircraft accident investigator. Opinions and conclusions expressed herein are those of the writers and are not official positions of The Society. The Editorial Staff reserves the right to reject any article that, in its opinion, is not in keeping with the ideas and/or objectives of the Society. It further reserves the right to delete, summarize or edit portions of any article when such action is indicated by printing space limitations.

Because of the recent resignation of former Editor Les White, and other necessary changes in the editorial staff, we regret the delay of this Proceedings publication.

Since a transcript of the "Debate" proceedings was not available during preparation of this issue, we apologize for the brevity of the summary and any errors or omissions made in its preparation.

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The Jerome F. Lederer Award

Nominations for the 1986 Award will close on March 31, 1986.

The award is given for outstanding contributions to technical excellence in accident investigation. Not more than one award will be made annually and presentation is at the ISASI Seminar. The recipient is selected by an ISASI Board of Award.

Any ISASI member may submit a nomination for this award. It must be sent to the Chairman of the Board of Award, and must include a statement describing why the nominee should be considered. This statement should be sufficiently descriptive to justify the selection but no more than one typewritten page in length.

This award is one of the most significant honors an accident investigator can receive, and so considerable care is given in determining the recipient. Each ISASI member should thoughtfully review his or her association with professional investigators, and submit a nomination when they can identify someone who has really been outstanding in increasing the technical quality of investigation.

Mail to: Dr. William J. McArthur
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MEMBERSHIP

Individual membership is available to persons who are, or have been actively engaged in the investigation of aircraft accidents, civilian or military, or in the promotion of air safety. The initiation fee is $35.00 and the first year's annual dues are $50.00 for a total of $85.00 U.S.

Corporate membership is available to firms engaged in air transportation, in the manufacture of aviation products or providing services that are aeronautical in nature. Submit a letter to the President of ISASI and forward the sum of $400.00 U.S. to provide an initiation fee of $100.00 and the first year's dues of $300.00.

Further information on membership may be obtained by writing:

Jack G. Young, Chairman
Membership Committee, ISASI
West Building, Room 259
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Washington, D.C. 20001

Table of Contents

THE JEROME F. LEDERER AWARD

1984

presented to

George B. (Skee) Parker

for

Outstanding Contributions to Technical Excellence

in Accident Investigation

Mr. Parker, Associate Professor of Safety at the University of Southern California, has achieved much in his twenty-two year career in aviation safety. As an aircraft accident investigator, expert witness, consultant, innovator of procedure, and educator, he has developed many successful investigation procedures, and advocated and trained over 4,000 aircraft accident investigators from all fields of the aviation industry. However, he is best noted for his vigorous pursuit of more effective accident prevention. His philosophy and ideas concerning accident prevention are manifested in the new ICAO Accident Prevention Manual. He has been chairman of the Accident Prevention and Investigation Department at USC, organizer and manager of accident prevention courses and a contributor to the formation of the university's master of science safety degree program. Recipient of several commendations from the U.S. Navy and U.S. Air Force for his work, by his example, leadership and knowledge, he has demonstrated technical excellence in accident investigation and prevention.

Keynote Address

by W.H. Tench

Mr. Chairman, ladies and gentlemen,—

It is a great pleasure for me to have this opportunity to meet many old friends in the field of aircraft accident investigation, and to add my welcome to all our members from so many countries on their visit this week to London. I am also conscious of the privilege of being asked to speak to you at this juncture in order to set the scene, so to speak, for what I am sure we all hope will be an informative, stimulating and successful seminar.

The theme of this conference is "Resources," and your seminar programme lists some of the more practical resources the investigator calls upon in the course of his work, that will be the subject of presentations at this meeting. Finding and protecting your wreckage, recording the scene with photographs and maps, reading out the flight recorders, and so on, and tomorrow we devote the entire afternoon to a debate on Human Factors.

But it is not only physical resources that are necessary to enable the investigator to make his proper contribution to air safety. There are certain somewhat less tangible features, conditions, characteristics, call them what you will, that we are included to assume are always present, but unfortunately this is not always the case.

Perhaps the first of these features is the integrity of the investigator himself (or herself), and on this subject I can do no better than to call your attention to the excellent article in the latest issue of "*Forum*" by Gerry Bruggink on this subject. Are we always totally honest with ourselves or do we seek unreasonably to find an excuse to reject that odd little bit of evidence that blows our theory as to what happened clean out of the window. The total impartiality of the investigator who is paid by his government to investigate the cause of aircraft accidents is not all that difficult to achieve, though even he has to turn and bite the hand that feeds him occasionally and comment adversely on his own national aviation administration. But for those who hold a position of some responsibility with a major aircraft manufacturer or an airline, or who perhaps provides the technical expertese for lawyers representing other interested parties, or possibly insurers who may have to face the financial outcome of an accident, their integrity as an investigator can in some circumstances be put severely to the test. There have been some who have failed that test, but those who consistently demonstrate the necessary high ethical standards exercise far more influence upon the official investigators than the 'smart Alec' who is too selective in his presentation of evidence. As the saying goes "You can't fool all the people all the time", and sooner or later a bad reputation will become known and the offender will be discredited and ultimately ignored.

There is a tendency on the part of the public always to assume that the person or commission or board of inquiry appointed to investigate an accident is necessarily competent professionally to conduct a searching and impartial investigation, but there have been occasions when this has proved to be otherwise. We shall hear this week from Frank Taylor, not this time the Frank Taylor who gained so much respect at the head of the NTSB Bureau of Accident Investigation, but Frank Taylor who since 1977 has been running the course on aircraft accident investigation at the Cranfield Institute of Technology in this country. There are, of course, other very good courses on the subject such as those at the University of Southern California and in Sweden, also we should not forget the significant contribution in this field that was made by ICAO at Beirut until the political situation there put a stop to it.

These courses have done much to improve the quality of investigations and the standard of accident reports, but much remains to be achieved. The background of any potential investigator must be that of an aviation professional. Anyone who has not personally experienced the dry mouth and adrenaline flow that is stimulated by the engine fire bell ringing in the cockpit, and I don't include training flights or simulators in this context, is not best qualified to criticise the actions of the crew who are faced with the reality. Similarly any engineer who has not failed to detect a hair-line crack that is suspected in a highly stressed component should hesitate to condemn without qualification another who under pressure to maintain schedules and cost limitations, failed to identify a crack in the field because of dirt and paint in the area, not to mention the possibility of poor accessability caused by adjacent structure and, maybe, bad light. I have read in a recent accident report a long argument as to whether a pilot was right or not to turn back rather than press on to destination in a particular emergency that takes quite a long time to read, while the pilot had but seconds to make his decision. A properly qualified investigator will make that point clear and qualify his judgement accordingly.

Another important feature which we tend to assume is always present is the correct background of authority governing the conduct of the investigation; whether it be the laws of a sovereign state or the directions of a private company. If the national legislation of a state charges its investigators with the duty of seeking out the culprit who caused the accident, or if a particular state is interested only in absolving its own administration of any responsibility for an accident, its contribution to the enhancement of air safety is likely to be minimal. There are such states with this type of legislation and the prudent investigator should be aware of them. Also there are still too many states in which aircraft accidents in their territory are investigated by the military authorities. The authoritative military approach towards accidents is altogether inconsistent with civil procedures and the knowledge of Air Force personnel of operating wide-body jets is seldom sufficent to conduct a competent investigation. On the question of impartiality, I know of at least two separate occasions when investigation of ATC aspects of the accidents were conducted by the authorities responsible for the efficiency of ATC and in both cases the absence of such efficiency was a primary factor in the accidents. On the same theme, a company which directs its participating investigator employee to try to divert any adverse criticism of its products or practices regardless of their relevance to the cause of the accident is guilty of obstructing the pursuit of higher standards of safety in the air.

It is sometimes easier to move mountains than it is to change the law in some states, and company directions can remain obscure or even unwritten, consequently it may not be easy to bring about the changes that are necessary. However, the investigator who is confronted with such adverse circumstances is not entirely powerless to redress the balance of fairness and justice. At national level ICAO has set the pattern and specified that the fundamental objective of the investigation is the prevention of accidents and incidents not the apportionment of blame or liability. It is my submission that investigations that do not measure up to this criterion are invalid and do not merit the serious attention of the aviation community. As for those organizations whose instructions to their own participating investigators are not consistent with the ICAO objective, the simple refusal of inclusion in official investigations should provide the necessary incentive for them to change their ways.

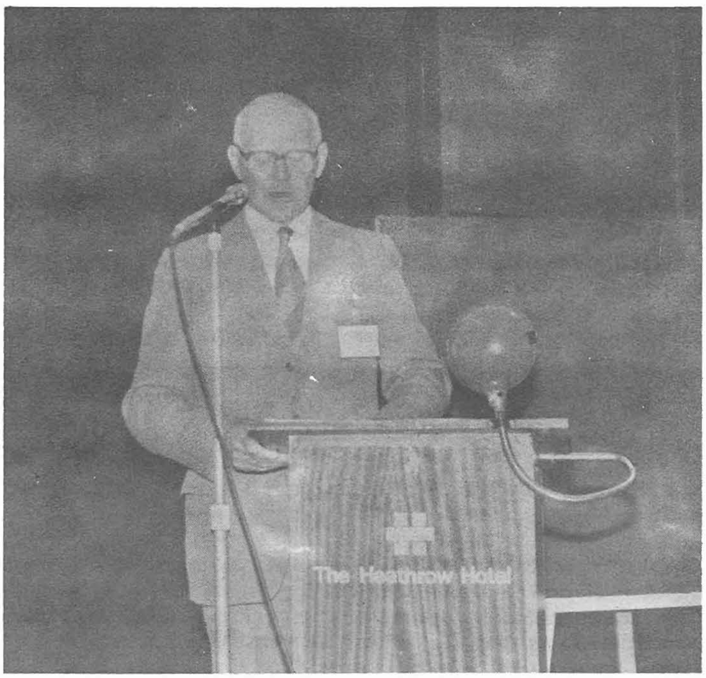
Whilst on the subject of ICAO I would like, if I may presume to do so, to congratulate the Secretariat on their production of a most practical and informative Manual of Accident Prevention and I commend its use to you all. This is not to imply that I am content that ICAO has done everything that needs to be done in the area with which we are concerned. I am amongst those who think that ICAO should strive to amend Annex 13 to specify that the publication of civil aircraft of international air navigation in order that all the world might benefit from the lessons learned and, incidentally, that those states whose accident investigation practices and reports that do not come up to the standard might be revealed for their inadequacy.

The matters I have mentioned may or may not fall under the category of resources; they are at any rate circumstances in which members of this Society have to operate and they are largely matters which the individual investigator cannot do a great deal to correct, but now that we are armed with the right of an accredited representative to append to an official report a dissenting minority opinion by means of paragraph 6.11 of Annex 13 to the ICAO Convention, we are able to reveal to the press and public those administrations whose standards fall short of what is necessary in an activity that is so closely associated with the safety of the public in the air. At least that is so where publication does take place.

It remains, therefore, for us to ensure that our own standards are as high as we can make them. I trust that we may all be able to learn something from this meeting, not only from the platform speakers but also from the valuable resource that is represented by the substantial knowledge and experience of everyone present here.

I notice from the Seminar Programme that there is only a single fifteen minute period devoted to general discussion at the end of today's session though of course everyone is invited, indeed urged to participate in the debate on Human Factors tomorrow. Perhaps there will be an opportunity to expand the discussion time as the meeting goes on. However that may be there is ample time during coffee and meal breaks and inevitably in the bar in the evenings to indulge in our favorite passtime of talking shop.

So without further ado from me let us get on with the job. I wish you all a successful and enjoyable meeting.



William H. Tench

Underwater Resources

Underwater Resources
Richard McKinlay, MBE, AFC
Senior Inspector of Accidents (Operations)
UK Accidents Investigation Branch

Introduction

As accident Investigators you will know that there is nothing that hampers an investigation more than no wreckage, no recorders, no survivors or bodies and no precise idea as to their geographical location. This is the state of affairs that would confront the investigator of a large transport aircraft just disappeared at sea. We, in the AIB, have luckily not been confronted by such a tricky problem but we have been involved in the investigation of several North Sea helicopter accidents. We have therefore become familiar with the problems of location and recovery of aircraft wreckage.

The problem

Up until now, in the North Sea, we have been lucky enough to have a 'splash point' accurate to within 3 or 4 square miles but we realize that we have been extremely fortunate so far and we are therefore working towards a day when we may be required to search a very large area for important wreckage. The search of a large area will undoubtedly be very expensive and time consuming. It is therefore essential to have considered the problem in detail before the event forces hasty action upon you.

Search techniques

The methods of underwater search all stem from military and oil related techniques to detect objects on the sea bed. There are basically three possible methods:

a) Side scan sonar
b) Magnetometers
c) Acoustic beacon detectors

Side scan sonar has given us disappointing results. It is very dependant on sea state as the motion of the towing vessel affects the side scan picture and the sweep width is usually not very great. Furthermore, light alloy structures seem to be transparent to some side scan systems. We have found the side scan of use to classify objects found on the sea bed by some other method.

Magnetometers will detect large iron objects but aircraft structures are not usually very easily detectable by this method, especially if they have broken up on impact with the water. Furthermore, in many areas of the world there are many uncharted wrecks and other metallic objects on the sea bed all of which may give rise to false hope when searching for wreckage.

The most successful method of detection in our experience has been using the acoustic beacon fitted to all transport aircraft. This device emits a 'ping' of acoustic energy about once per second as soon as the beacon is immersed in water. It will continue to radiate for about 30 days. Using suitable detection gear it is possible to locate and then home on this acoustic signal. The usual method of detection is by means of a hand held device which is only really suitable for use from small boats. This places a severe limitation on search capability as small boats are not suitable for use in high sea states, poor visibility or at night. Experiences in the North Sea, particularly in winter weather, have led us to believe that this is a most unsuitable method of search. Furthermore, although the hand held device is quite good at providing directional information it is not an effective device for obtaining the initial detection because it cannot be used with the boat moving. If a large area needs to be searched a detection device which can be used in all weathers and all sea states is therefore necessary. Because of the many limitations of the hand held detector we decided to look for an alternative method and after extensive inquiries we discovered that no existing system was either directly applicable to our requirements or easily modified to meet them. We therefore came up with the basic requirements for such a system and circulated them to various companies who have experience in this field.

Richard McKinley, AIB

Requirements

The requirements we asked for were as follows:

a) The equipment should be suitable for use in both shallow and deep parts of the continental shelf.
b) It should be optimised for initial detection of the 37.5 kHz signal.
c) Designed to minimize the self generated ship noise. (The ships typically used are North Sea survey vessels.)
d) Suitable for use in high sea state.
e) Contain a visual display as well as audio monitoring.
f) Capable of searching large areas relatively quickly.
g) Contain depth and temperature sensing equipment.

The detector equipment

After considering various suggestions we finalised on a towed "Fish" system whereby a number of hydrophones contained within a towed body, connected by cable to the ship, is used to transmit any signal received from the acoustic beacon up to a processor conveniently located on the ship. Because it is necessary to keep up the search for long periods, and operator fatigue is obviously a problem, we also specified a printer to give us a look back capability should the operator fall asleep. The device is towed through the water at the optimum depth for the search, and as the towed body comes into detection range of the acoustic beacon then a light illuminates to indicate the detection and also denotes which 15° sector the detection has occurred in. The printer will print the time of the detection and the sector in which the detection occurred, also, as the bearing changes the printer will print the time that each new sector was entered. By correlation with the ships navigation system and time it is possible to plot a running fix on the most likely location of the pinger and hence the wreckage. The diving ship can then be accurately positioned overhead the wreckage using the existing hand held equipment in conjunction with either a clump mounted side scan sonar or underwater TV camera. Diving operations to recover the wreckage can now begin.

Conclusion

We have developed a system which will allow us to search for acoustic locator beacons in all weathers and in such a way that large areas can be searched efficiently and relatively swiftly. There is little skill required by the operator, however, a knowledge of underwater acoustics will always improve the efficiency of any search. The only variables required to be decided by the search co-ordinator are the track spacing, dependant on likely detection range, and the optimum depth for the towed body. These can be readily determined on entering the search area by trial and error against an acoustic beacon laid for ranging purposes and then recovered. We are still developing the capabilities of the system and have yet to use it operationally. However, we are sure that we have given ourselves a considerable advantage over the existing hand held system and we hope to save both time and money during our next search. We also hope to have recovered the wreckage some considerable time before we would otherwise have done.

Richard McKinlay, MBE AFC

Richard McKinlay started flying in 1959 and joined the RAF in 1960. He served on maritime patrol squadrons and in various training roles. He commanded the first Mk 2 Nimrod maritime reconnaissance squadron until he joined the AIB in 1981. Amongst his normal investigation duties he is also project officer for the AIB's acoustic detector system.

The Police Role at Aircraft Accidents

Inspector George McColl
Metropolitan Police - Heathrow

This paper outlines the actions to be taken by the Metropolitan Police in the event of a major aircraft accident at or in the vicinity of Heathrow Airport. Similar action plans will be prepared ready for use throughout the Metropolitan Police District. These plans are based on ICAO and IATA recommendations and whilst I cannot speak for other police forces in U.K. or other countries, most, if not all, will have similar plans to hand.

Role of the Police

Before examining the role of police, we must first examine briefly the role of the other services. Firstly the ***fire service:*** fire fighting and rescue; the ***ambulance and medical services:*** immediate treatment of casualties and subsequent removal to hospital; yourselves, ***the accident investigators:*** the wreckage and accident investigation; finally, ***the coroner or his equivalent:*** the bodies and causes of death. Everything appears to be covered, so what do police do?

The aeroplane crashes, there is noise, perhaps smoke and flame, panic, survivors, rescuers, gawpers, well intentioned nuisances, possibly looters, all over the crash site, all charging round, over and through wreckage and property.

It is my contention that the *principal* role of police in these circumstances is to *regain* and then *retain* order and provide as clean an environment as possible so as to allow all the other services to carry out their appointed tasks as quickly and professionally as possible.

The Police should:

Control	The Crash Site Access and Routes to and from Crowds Press Traffic
Co-ordinate	All Services and Specialist Team Efforts
Preserve	Evidence of Crash/Crime Locations of wreckage Location of bodies
Prevent	Further unnecessary damage to wreckage Looting Any other crime Contamination of Scene

HOW?

Police in U.K. have been concerned with aircraft accidents ever since there were aircraft accidents and in those early days one man could comfortably deal with the early aviation accident, involving as it did only one or two persons and little damage, but now, when we are contemplating the horrors of the modern accident with passenger lists numbered in hundreds, we have to be organised in advance and ready to deploy very many officers. Let us now examine the main police functions.

Command and Control

Whilst no one man is in 'command' during the early stages of an accident it falls to the Police Incident Officer to set up a command and control organization. Whilst no police officer worth his salt would dream of instructing the Senior Officer of another service in how to conduct his operation or deploy his operational vehicles he *will* have a function in the disposition of ancillary vehicles and services that are not operationally necessary on site. He has the responsibilities of ensuring access, to and from the site, of essential services; direct liaison with the Fire Chief regarding dangerous cargo; with medical authorities regarding survivors, and many other agencies, airline etc., in addition to his own responsibilities. Taking everything together this will require him to set up a command area, where the incident control vehicles of all services can set up together and be linked one to another by field telephones. These vehicles incidentally will be the only vehicles on site permitted to operate roof beacons, to avoid confusion and clearly identify the command area.

Co-ordination

Assistance will be arriving at the site from all points of the compass from all emergency services, including in certain circumstances the military. If this aid is to be of use, it must be properly controlled, otherwise individual units will park where they can and crews will go to work piecemeal with a consequent loss of co-ordinated effort. To overcome this problem a rendezvous point must be established by police to which all aid can be directed and subsequently fed onto site as required by senior officers of the respective services and so used to best effect. A good method of communication must be quickly set up between all essential services so that vital information may be passed between them as soon as it is available. At a large accident site, one cannot afford to send a runner to find a particular Officer of another service. To this end, police undertake to supply a Police Liasion Officer, equipped with a police radio, to senior officers of fire, ambulance, accidents investigation and where appropriate, airport and airline operations. Together with the Command Centre, this should be sufficient to ensure a co-ordinated response and an awareness of other services needs and problems.

On Site Operations

Police must take full responsibility for various functions at or around crash site. These include:

Dispostion of Victims

Protection and Recovery of Property, Personal and Evidential

Control of Press

Control of Crowds

Control of Traffic

Victims

Police must eventually account for every person on board the aircraft and must therefore know the location of every survivor and fatality. They must establish a place of safety to which the comparatively uninjured may be taken for documentation and possible interviewing by police. Was it a criminal act? AIB re. survivability; airline; Customs and Excise or Immigration. They must post liasion officers to hospitals where casualities are taken for the same reasons and should liase with ambulance authorities as to which hospitals are to be used and best routes to and from them. Finally a temporary mortuary that can accommodate the number of bodies involved, with working space for identification teams, pathologists and storage areas, light and water, but above all security and privacy has to be found.

Property

This will be a mammoth task. On todays public transport aircraft passengers are permitted by most airlines to carry two items as cabin baggage. On a full 747 this will amount to between 750-800 items, always supposing none split open on impact and this takes no account of individual items on the person, i.e., jewellery, wristwatches, wallets and purses etc., nor of hold baggage. There may in addition be evidential property to look after, i.e., C.V.R. and F.D.R. Officers are instructed on no account must these particular items be touched, just located, marked and guarded until recovered by specialists. It will be necessary to establish and man a property bureau for each accident, to ensure property is properly dealt with and eventually restored to owners or next of kin.

Press and Traffic

You are intelligent men and there is no need for me to labour these points. Sufficient to say there will be problems and they will require manpower. Traffic congestion can be expected for example on main roads within 25m radius of Heathrow.

Crowds

Apart from the obvious, it will be necessary, on airport, to effectively control those persons who are there to meet or see off relatives or friends on the accident flight. They may well be in a hysterical state and this could develop into a public order situation. There is another aspect of crowd control that needs to be dealt with firmly by police. As work at the scene progresses large numbers of emergency service operatives may well gravitate to the site even though they have no specific task to perform and this will possibly prove to be the hardest crowd to control.

Off Site Operations

Police activity will not be confined to the immediate crash site. As mentioned above, police will be responsible for traffic control over a very wide area. A major accident will inevitably attract hordes of sightseers and it may well be necessary to restrict traffic on roads near the site solely to emergency traffic. This will place a huge strain on diversion routes and will have a cumulative effect. In 1972 when PI crashed just south of the airport, traffic control and diversion eventually involved 4 separate police forces, with the furthest out control point 26 miles from the accident site.

Police will have a major role to play in victim identification and informing next of kin of the status of their relatives. To this end a casualty bureau will be opened and manned on a 24 hour basis to deal with the expected thousands of telephone calls that will be generated world wide. To give you an idea of numbers, when the BA helicopter crashed off the Scilly Isles, there were only 26 persons on board, but over 4,000 enquiries were received, and after the bomb explosion in Terminal Two approximately 1,200 calls were received in 12 hours, in both cases incidentally, a percentage of the calls were of an obscene or indecent nature. Officers will be posted to the Victim Identification Group working with pathologists and certain specialists, under the coroner; to the place of safety for uninjured passengers; to the Special Information Bureau for personal callers at the airport and to each hospital where casualties are taken. These officers will have a twofold role of obtaining personal details *and* of keeping order.

Administration

Finally with so many police officers employed there must be a Central Base Station to administer to all their needs. The Base Station must be in a position to answer to every requirement of the Incident Officer at the site, and officers at other locations. It must be established to directly control this one event. The Incident Officer may require additional equipment or manpower and this must be supplied virtually on demand. The large number of officers employed will require feeding, toilet facilities at site, transport, manpower reliefs etc. Therefore the Base Station will require to have specialist officers available from each of these branches to service the needs of the officers at the various locations.

Conclusion

The amount of detail required to be covered under the role of the police may well surprise you, as it has surprised many police officers in the past, but when you examine these requirements, who else is going to deal with them? The question posed at the start of this paper when discussing the roles of the services was "now that everything is covered, what is the police role?" It is to be hoped that this paper goes some way to providing the answer.

The Author

Inspector George McColl

George McColl served in the Royal Air Force from 1952 to 1958 as an Air Electronics Operator on Maritime Reconnaissance aircraft. He then joined the Hampshire Constabulary, and transferred to the British Airports Authority Police at Heathrow in 1973. This force later amalgamated with the Metropolitan Police. George has specialised in contingency planning at Heathrow and has been the incident officer at the scenes of several accidents.

Aircraft Accident Photography—An Update

by Richard H. Wood M00598
University of Southern California

Introduction

This paper supplements the paper presented to the International Society of Air Safety Investigators in San Francisco in 1980.[1] Except for some fundamental ideas about aircraft accident photography, this paper describes photographic techniques not covered in the earlier paper.

Equipment

The camera of choice is still the 35mm Single Lens Reflex (SLR). There are better cameras, but considering everything; size, weight, cost, through-the-lens viewing, film format and versatility, the 35mm SLR will remain the field investigator's favorite for the forseeable future.

The lens of choice is a macro lens with the capability of focusing from infinity to a 1:1 close-up. This eliminates the need to carry extra lenses, diopter rings, or extension tubes. If there is room for a second lens, it should be a wide angle lens, perhaps 28mm. This is useful for overhead shots and situations where the photographer is too close to the subject. An example would be the instrument panel photographed from the pilot's seat. The 28mm wide angle lens will roughly double the amount of instrument panel that can be covered with one picture.

Additional minimum equipment needed is an electronic flash, an extension cord for the flash, a locking cable release for the shutter, and a small tripod. (Photo 1.)

If the investigator does not own a macro lens, reasonably good close-up shots are still possible with a "normal" 50mm lens. This is done with a lens reversing ring—an inexpensive piece of equipment. One side of the ring screws into the front of the lens and the other side fits the camera mount. This permits the lens to be mounted backwards on the camera and — voila—a close-up lens. (Photo 2.) The 50mm lens which normally can't be focused closer than about 15 inches (38 cm)—film plane to subject—can now be focused at about 8 inches (20 cm). A good discussion of this technique is contained in Marc Goldsmith's article on Industrial Macro Photography.[2]

This scheme is not without its drawbacks. First, the reversed lens becomes almost a fixed focus lens. It will focus *only* at about eight inches which is somewhat limiting. Second, and perhaps more important, the camera will no longer automatically close the lens diaphragm to the proper aperture as the shutter is released. The photographer must either shoot with the lens wide open or hold the diaphragm to the proper f-stop with the preview button available on most lenses.

Still, if there is no macro or close-up lens available, this will work. It will even work without the reversing ring if the photographer can hold the front of the lens flush against the camera mount, focus it, hold the diaphragm closed, and release the shutter. This requires a tripod and a certain amount of manual dexterity. It also increases the risk of a spoiled picture due to improper focus or exposure.

If the photographer does not have a tripod—and needs one—a camera clamp is a very useful tool. This is essentially a

Photo No. 1.
Minimum equipment. Camera, lens, electronic flash, tripod, cable release and flash extension cord.

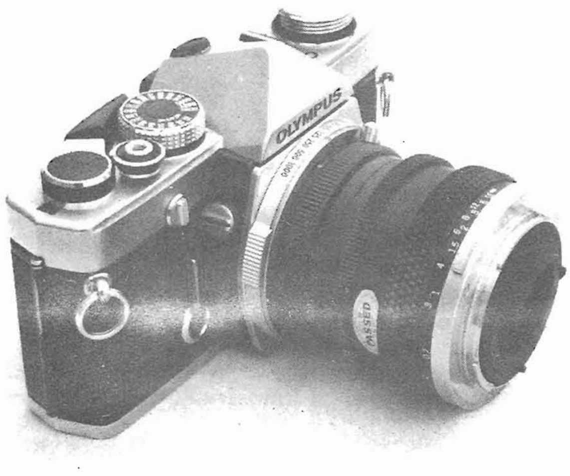


Photo No. 2.
Lens mounted backwards on camera using reversing ring.

C-clamp with a swivel fitting that will screw into the tripod socket on the camera. About the same result can be achieved by welding or attaching a tripod fitting to a carpenter's C-clamp or a large pair of vise-grip pliers.

If none of these are available, the photographer's last resort is a "bean bag" tripod. A two-pound bag of rice works quite well. (Photo 3.) In humid climates, the rice can also be used as a moisture absorbent to keep the equipment and film dry.

Picture Identification

Identification of pictures is still important. One easy system involves identification of individual film rolls, a photo log for pictures within a roll, and proof sheets as a means of matching the pictures with the log.

Identify film rolls by using the first frame of each roll to photograph an "Identification Board" listing roll number, date, subject, and the photographer's name and address. If a macro lens is available, a business card with the date, subject, and roll number added can be used.

Maintain a log of pictures taken on that roll by subject, direction, conditions, etc. A small tape recorder is useful for this.

Have contact proof sheets made of each roll of film. A proof sheet is an 8x10 print showing up to 30 direct prints of 35mm negatives. Done correctly, the print in the upper left hand corner is the roll identification picture. The remainder will be in the order taken with the frame numbers visible on the edge of each film strip. Thus the proof sheet becomes the file copy of the prints and the frame numbers correlate with the photo log. (Photo 4.)

Use of proof sheets is also economical. It allows the photographer to take multiple pictures and select only the best among duplicates for final printing.

There are, of course, other ways of identifying pictures. A replacement back is available for most 35mm SLR cameras which allows the photographer to add a number, date, or time to the negative. The same result can be achieved by adding a numbered card to the scene. Sellers of law enforcement and evidence collection equipment offer rolls of self-adhesive tape printed as a series of two-inch rulers. Each ruler has room for a number and subject to be written on it. Removed from the roll and stuck on the subject, it becomes both a picture identification and a size reference. (Photo 5.)

Any of these methods depend on the use of a photo log. A numbered picture is of no value if no one remembers the subject.

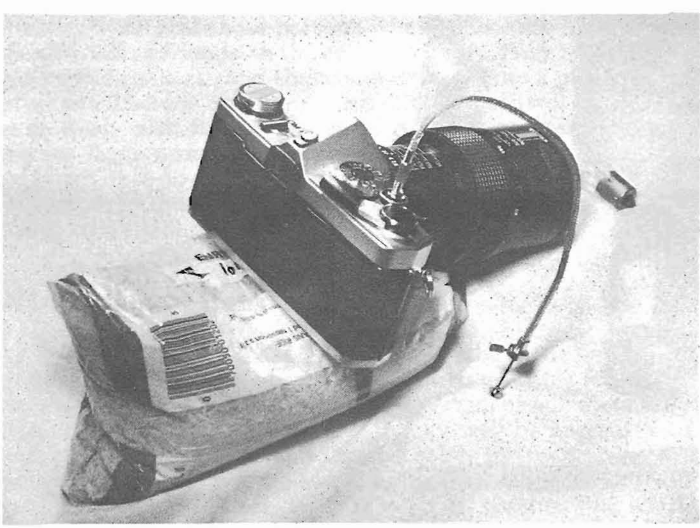


Photo No. 3.
The "Rice Bag-Tripod" Trick.

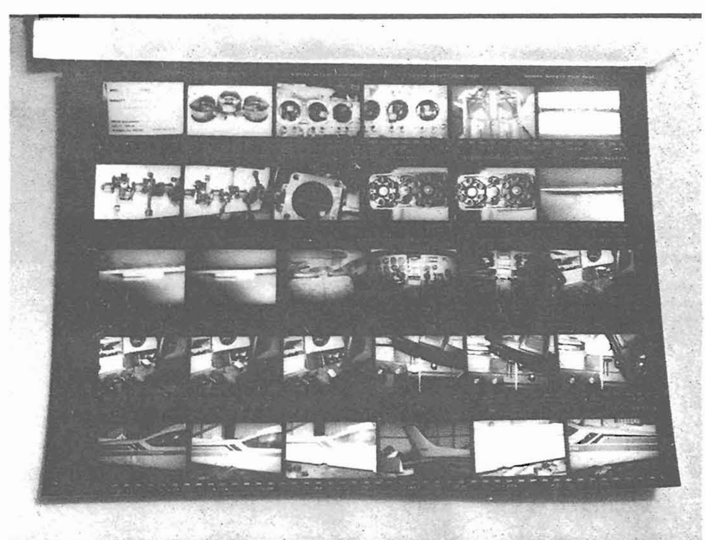


Photo No. 4.
Proof Sheet.

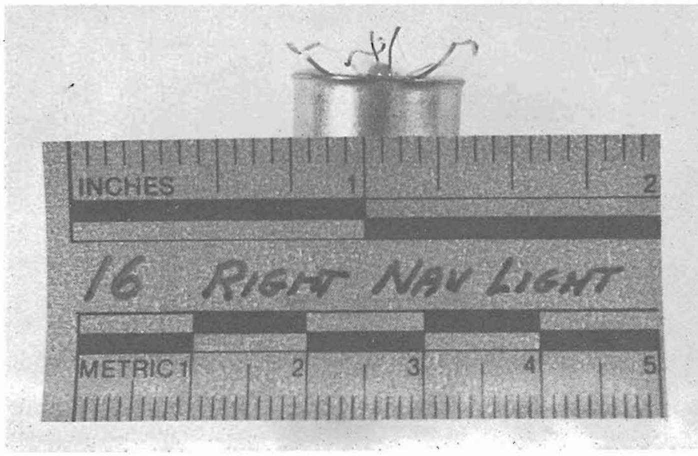


Photo No. 5.
Picture identification using police department evidence stickers.

Legal Considerations

If there is a possibility that the pictures taken of the accident will later be admitted as evidence in a court of law, some additional precautions may be necessary.

In some jurisdictions, a photograph with something added (such as a number or a size reference) is considered "tainted" or "adulterated." It is no longer a true depiction of the scene.[4] The solution is to take duplicate pictures—one with the size reference and number and one without.

In the printing process, it is very difficult to enlarge a negative to an *exact* multiple on the negative size. Most enlargements are "cropped" slightly in one dimension or the other and the material omitted is usually insignificant as it comes from the edges of the picture. Moreover, it may be desirable to deliberately "crop" a picture by enlarging an important feature to fill the entire print. Thus a small part of the picture may be enlarged "out of context", so to speak, and the remainder of the picture ommitted. It is not possible to look solely at an enlargement and say with certainty that it shows everything that was on the negative—and the lawyers know this.

This is another advantage of proof sheets. The contact print on the proof sheet does show everything that is on the negative and it can be used as a means of validating the enlargement.

Depth of Field

Depth of field is sometimes a problem for the aircraft accident photographer. Depth of field is merely the distance, front to back, that the picture is in focus. In accident photography, the problem usually occurs during close-ups. All items that are important to the picture cannot be brought into focus at the same time. There are, generally, four solutions.

1. Shoot from a different angle—one that brings all parts into the same plane or distance from the camera. This, of course, is not always possible or practicable.

2. Back up. Depth of field improves with distance. This likewise may not be a satisfactory solution because it is the close-up that is desired.

3. Focus mid-way (about 1/3 of the way, actually) between the important items in the picture. This is not a very good solution as it merely distributes the out-of-focus condition evenly. In extreme close-ups, the depth of field may only be a fraction of an inch and this solution won't help much in any case.

4. Use a smaller aperture. This is the best solution, but the one least used. Depth of field improves significantly with reduction in aperture. Set the lens to the highest f-stop (smallest aperture) available and then slow down the shutter speed to get a satisfactory exposure. This method will frequently require a very slow shutter speed, which means use of a tripod for the camera and a cable release for the shutter.

Light Table Photography

Some small objects, cockpit warning light bulbs, for example, are very difficult to photograph because of reflections from the glass case of the bulb. The solution is to illuminate the object from behind as a professional photographer would do with his light table.

While most investigators do not possess this convenience, they probably have any number of suitable substitutes. All that is needed is a translucent panel and the ability to aim the electronic flash from behind the panel by use of the extension cord. A slide-sorting tray or a translucent plastic refrigerator container will work well. A styrofoam plastic drinking cup can even be used.

Obviously, the exposure and lighting control for this scheme is something of a guess. Several shots should be taken at different exposures.

Stereo Photography

Photography is a two-dimensional depiction of a three-dimensional world. Sometimes it is important to show depth. There is available a stereo camera which has two lenses and can take a pair of 35mm stereo pictures. These cameras are fairly expensive and somewhat limited in their capability. The same results can be achieved with a standard 35mm SLR and an understanding of the stereo process.

The idea is to duplicate with the camera what the eyes see—one eye at a time. With the camera on a tripod, select a point of focus and take a picture. Now move the camera approximately 2¼ inches (about 5.7 cm) to either side. A small error here is not critical.

Now re-aim the camera on the same point of focus and take another picture. This will produce a "stereo pair." Under a stereo viewer, the pictures can be slid around until the images merge. At that point, the brain will take over and create a three dimensional image. Stereo viewers can be obtained at many optical shops and most surveying equipment supply stores.

Montage Photography

The camera, even with a wide angle lens, has a very narrow field of view compared to the human eye. This can be overcome, somewhat, by taking a series of overlapping shots and then edge matching the pictures and re-photographing the result. This is particularly useful when trying to show what a witness saw (or could have seen) or what a takeoff or landing pattern really looks like.

This can be done with a hand-held camera, but it works better if the camera is mounted on a level tripod that can be swiveled. Start at one side of the scene and try for about a 50% overlap on each picture. (Photo 6.)

Shadows

Another method of achieving some idea of depth or texture in accident photographs is to take advantage of shadows. The idea of creating shadows by controlling the angle of light was covered in the previous paper.[1] If this is not possible, try adding a shadow by introducing something into the picture with a perfectly straight edge. This straight edge will cast a shadow on the object which will bend or conform to its contours or texture. (Photo 7.)

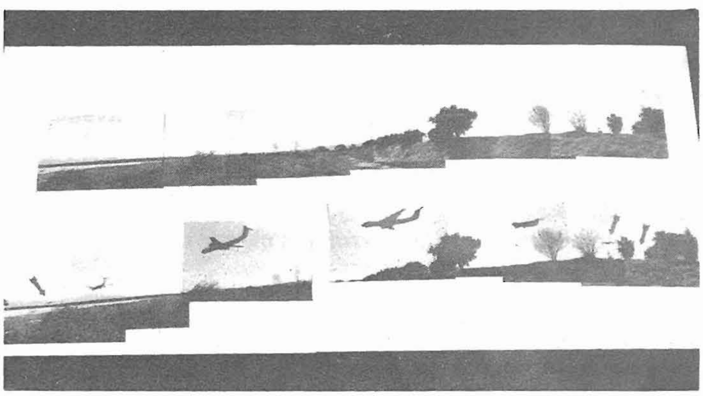


Photo No. 6.
Photo Montage showing witness view (top) and actual aircraft overflight from same vantage point.

Photo No. 7.
Use of a straight-edge to create a shadow to illustrate depth.

Photo No. 8.
Model Photography. Model is attached to stick and held by assistant off camera.

Photographing Model Aircraft

Frequently, the investigator will want to photograph a model airplane to illustrate some point about the accident. One easy way to do this is to mount the model on a thin dowel and have an assistant stand off-camera and hold the plane in the proper attitude. If the dowel is painted to match the background, the dowel will "disappear" in the picture. (Photo 8.)

Photographic Mapping

The process of scaling accurate dimensions from a horizontal photograph is not new. It has been used for years by surveyors and vehicle accident investigators. It has not been used extensively in aircraft accident investigation, probably because significant measurements can usually be taken directly at the scene. Nevertheless, it is a useful technique available to the investigator.

Basically, this involves having something of known dimensions in the picture. A clipboard will work, but the process is easier with something of standard size. A grid composed of four one-foot squares with the borders and diagonals plainly marked will work quite well. If it is placed somewhere in the foreground of the scene with the nearest edge parallel with the bottom of the picture, it will become a "perspective grid." With the known dimensions of that grid, a competent draftsman can establish a perspective grid system over the entire photograph which will allow accurate measurements of objects within the picture. (See Photos 9-12.)

Accuracy drops off as a function of distance, but this can be overcome by taking several pictures from different locations; each with the grid in the foreground.

This method works best on fairly level ground and even better if the photographs can be taken from overhead. This is a good situation in which to use the "camera-on-the-pole trick described in the earlier paper.[1]

The definitive work on this subject is by J. Stannard Baker, "Perspective Grid for Photographic Mapping of Evidence."[6] Another excellent article is Paul Wohfeil's "Perspective and Photogrammetry."[6]

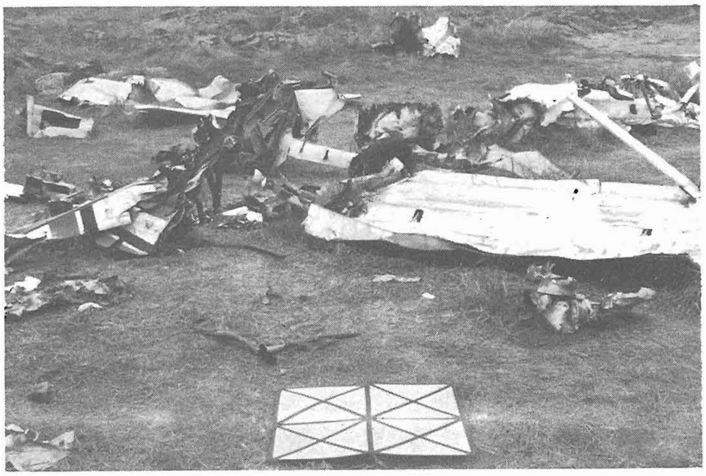


Photo No. 9.
Perspective grid in foreground of wreckage scene.

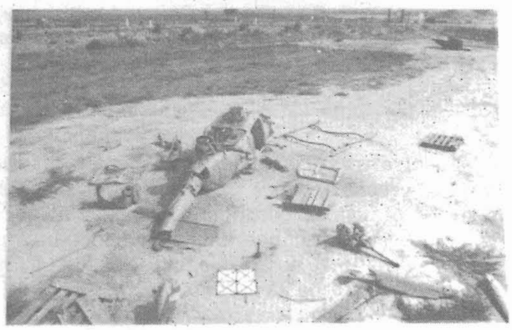


Photo No. 10.
Print of perspective grid picture overlayed with plastic.

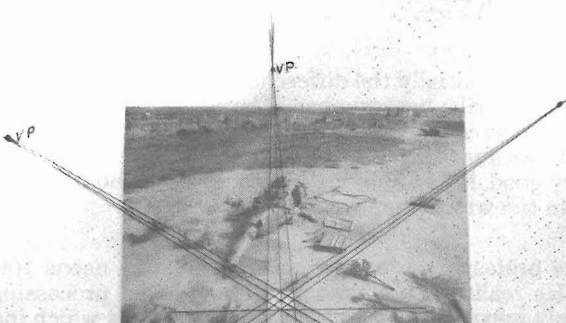


Photo No. 11.
Vanishing points established.

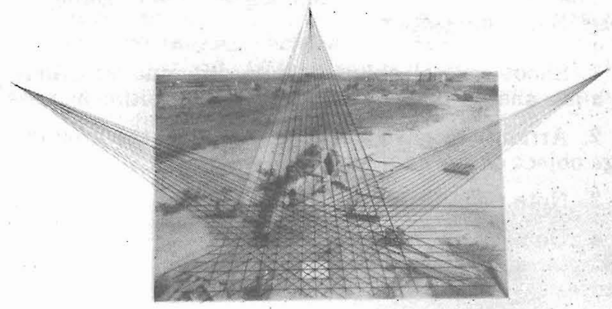


Photo No. 12.
Perspective grid developed.

Mirrors

As it turns out, mirrors are good for things other than just getting the camera into inaccessible places. A mirror can, for example, be used to show both sides of an object in the same photograph. (Photo 13.) Caution. Depth of field may be a problem. The reflected image may be out of focus.

Also, a mirror can be used to solve the photographer's dilemma. A picture of the inside of something is needed and it must be illuminated with flash. Unfortunately, there is only room for the camera or the flash—but not both.

You can, of course, purchase a ring light—a neat flash unit that fits around the lens and allows you to get both into the subject. Failing that, try a mirror. Illuminate the interior of the object directly with the electronic flash (on an extension cord) and focus on the interior through a mirror.

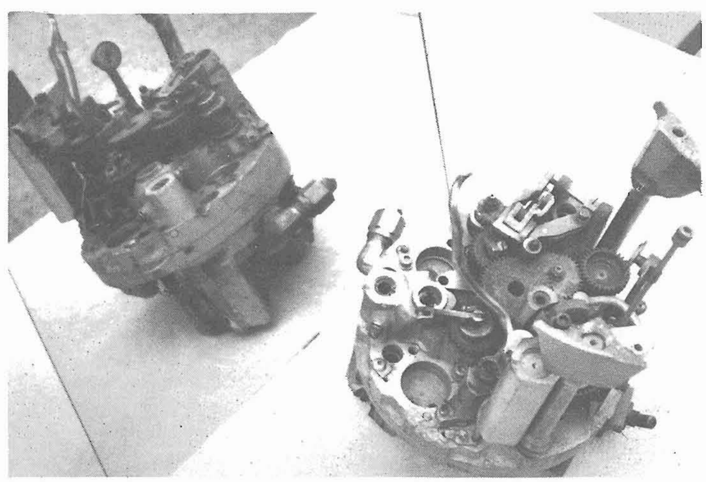


Photo No. 13.
Use of mirror to show both sides of a fuel control unit.

Aerial Photography

The 35mm SLR can do an adequate job of aerial photography. Some suggestions:

1. Shoot several obliques from different directions and get a few shots from as nearly a vertical position as possible.

2. Arrange to have a size reference on the ground. Any large object of known dimensions will do.

3. Note the altitude of each photograph.

4. Do not rest the camera or your arms on the aircraft or helicopter structure. This will induce vibration and spoil the picture.

5. If you must shoot through a window, hold the camera as close as possible to the window to eliminate reflections.

6. Keep the bottom edge of the film plane (camera) level with the horizon. Otherwise, the resulting picture will be misleading.

7. Always take two pictures per shot. If you shoot two pictures in rapid succession, you will have a "stereo pair." Viewed under a stereo viewer (see preceding discussion) these pictures can show terrain features, depth and detail and be of significant help to the investigator.

Some excellent aerial photography techniques are described in Jack Lord's article on Oblique Aerials.[7]

Night Pictures

The general subject of night photography was covered in the earlier paper.[1] The technique of "painting with light" yields consistently good results providing the photographer has a tripod and a locking cable release available. Sometimes, this technique produces results superior to daylight photography because light is added to areas which would otherwise be in shadow. (Photos 14, 15.) The investigator should test this technique before needing it in the field in order to understand the procedures and develop confidence in the results.[8]

Photo No. 14.
Daylight picture of wreckage.

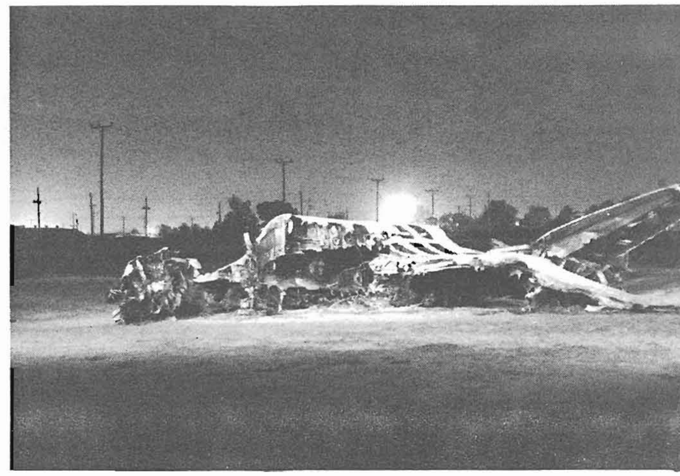


Photo No. 15.
Night picture of same wreckage from same position as Photo 14. This one was "painted with light" using six flashes at about fifteen feet from the wreckage.

Summary

In one sense, aircraft accident photography should be quite easy. The wreckage does not move much; there is no need to strive for beauty or composition; and a minor error in exposure is of little significance if the final product satisfies the requirement. In short, aircraft accident photography can be fairly sloppy and still be satisfactory.

In another sense, though, accident photography imposes some unique constraints on the photographer. First, the photography is done under field conditions with whatever equipment the photographer can reasonably carry to the site. This frequently requires some "make-do" type ingenuity. Second, there is seldom a second chance. The photographer must get a useable picture the first time, because the wreckage or the scene will never look like that again.

The solution to both these problems is the same; take a lot of pictures.

This is essentially the difference between the amateur and the professional photographer. The amateur needs 100 pictures of the wreckage. He takes 100 and expects all of them to be good, because he needs all of them. If several of them are not very good, he is out of luck, because he cannot duplicate or re-create the wreckage scene.

The professional, on the other hand, also needs 100 pictures. He realizes, though, that film and film processing are relatively inexpensive, so he takes 500 pictures which include a lot of duplicates and "bracketed" exposures. He looks at those 500 on proof sheets and prints only the 100 that he really wants. He may take a lot of bad pictures, but he doesn't print them—and he always gets at least one good picture of each subject. There is no reason why the aircraft accident investigator can't emulate the professional photographer.

In summary, the closing remarks in the previous paper on this subject[1] are worth repeating.

1. Get organized.
2. Stick with simple, versatile equipment.
3. Keep track of what you are doing.
4. Do it in some logical order.
5. Don't be in a hurry. Take the time to do it right.

And finally, take a lot of pictures.

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THE AUTHOR

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Richard Wood, USC

The Role of the Aviation Pathologist in Aircraft Accident Investigation

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Royal Air Force Institute of
Pathology and Tropical Medicine

In 1954 the disasters to the two Comet l's occurred. Only human wreckage was recovered initially following these accidents, and the extent to which autopsies helped subsequent experimental work and final correlation of medical and technical evidence is well known to accident investigators (Armstrong et al 1955). The brilliant reconstruction of the two accidents can be described as representing the birth of Aviation Pathology.

As a direct consequence of the Comet disasters and the medical findings of that investigation, the Department of Aviation Pathology (now the Department of Aviation and Forensic Pathology) was established at the Royal Air Force Institute of Pathology and Tropical Medicine in 1955. The Department was initially tasked with investigation of the medical aspects of fatal RAF accidents and soon followed by requests from the Royal Navy and the Army.

The first military accident investigated by the department was on 9 November 1955. A Meteor Mk 7, with a crew of two, climbed to 35,000 feet. After a few minutes the captain, aged 38 and 25% overweight for his height, complained of feeling unwell. The co-pilot took over control and descended to 30,000 feet. The captain had an attack of spasmodic coughing (the "chokes"). 5-10 minutes later the co-pilot turned round to see the captain unconscious; he remained unconscious till the aircraft returned to base. The captain never regained consciousness and died 13 hours later from respiratory paralysis. Autopsy confirmed that cause of the respiratory paralysis was the result of decompression sickness.

In 1961 the Ministry of Aviation Committee Report on Civil Aircraft Accident Investigation (Ministry of Aviation. 1961) acknowledged the potential value of "aero-medical specialists" attending a major accident; the report went on to recommend that "aero-medical specialists participate in accident investigation whenever possible". In the previous year the Accident Investigation Branch (AIB) had requested the assistance of an RAF Pathologist for fatal light aircraft accidents.

In September 1961 there were special features about a DC 6 accident which resulted in a request from the AIB for a Royal Air Force Pathologist to assist in the investigation.

It can be said that now, in the case of fatal civil aircraft accidents it is routine practice for the AIB team to include an Aviation Pathologist.

The development of the department of aviation pathology service for aircraft accidents occurring in the United Kingdom is helped by the relatively small size of the country and accommodation within the existing medico-legal system. The centralisation of aviation pathology in the United Kingdom in one specialised department provides maximum experience for a small number of pathologists and in addition requires the development of liaison between that one department only and the civilian medico-legal authorities.

Aviation pathology is a comprehensive investigation of the fatalities whereby the post mortem findings can be correlated with medical histories, environmental factors, damage to aircraft and use of safety equipment. As the pathologist is dealing with persons, his task is primarily concerned with human factors.

In common with other members of accident investigation teams the main objective of the investigation is to find the cause and prevent similar accidents occuring in the future; if this is to be achieved the investigation must be as thorough as circumstances permit and this demands a multi-disciplined approach.

The Role and Scope of the Activities of the Aviaton Pathologist

1. Demonstration of disease in aircrew: disease may be causative, contributory or incidental.
   Microscopic examination of tissues is an essential part of the medical investigation. (Mason 1965).

2. Circumstantial medical history: The medical history of aircrew is very important and this will be the only means of revealing any occult illness not demonstrable at autopsy, for example, a history of neuropsychiatric disturbances. In addition, should pre-existing disease be found in aircrew to establish whether the disease was symptomatic and if so had any treatment been prescribed.

3. Toxicology: In the last decade the scope of toxicological analysis has greatly increased with improved methodology and modern equipment resulting in reliable detection of ethanol, carbon monoxide and drugs.

4. Means of Identification: Working in close co-operation with the police the pathologist has an important role to perform in assisting with identification. Means could include:

   Physical.

   Dental.

   Radiological.

   Clothing and personal effects.

5. Examination of Equipment: Seats, restraint harnesses and protective helmets.

6. Patterns of Injury: Similar or discordant.

7. Survivability: Death by drowning or burning in the absence of incapacitating injury.

8. Visit to the Accident Site: To obtain overall picture of the accident, position of bodies, examination of equipment and significance of various injuries.

Ideally, if at all possible, it is desirable that the pathologist should see the bodies at the crash site before they are removed from the wreckage. (Balfour 1981). However, there are a number of reasons why this may not be practicable, for example, the geographical position of the crash, and how soon the aviation pathologist can reach the scene. The removal of the bodies is a matter for the Police Officer i/c of the incident and HM Coroner to decide.

Disease

For practical purposes accident risk from cardio-vascular disease is the only medical disorder posing a significant safety threat to public transport aircraft and when properly designed and properly observed incapacitation drill is used, the risk of accident resulting from even the most adverse of cardiac events is a very remote one. (Chapman 1984).

Undoubtedly the commonest disease found in aircrew is coronary artery disease in its various degrees of severity. It may be entirely asymptomatic and many patients with quite severe disease have normal ECGs. It is not at all uncommon to find quite a severe degree of asypmtomatic coronary artery disease in apparently healthy aircrew killed in aircraft accidents. (Underwood Ground. 1981). On investigating a fatal aircraft accident where circumstances suggest pilot incapacitation, the aviation pathologist is faced with the problem of assessing the significance of severe coronary artery disease when found in the pilot (Underwood Ground. 1979). Even after thorough examination it may be difficullt to say whether the disease was;

A highly probable cause

A probable cause

A possible cause

or an incidental finding.

Illustrative cases

Case No 1.

In this case the degree of coronary artery disease was so severe that it could have led to sudden incapacitation at any time. The pilot was flying a Hughes 300 Helicopter with an electricity power line engineer as his passenger. They landed on a small plateau in the Welsh Mountains for a coffee break. The pilot took off and after about 15 seconds in the hover the aircraft started a slow transition on a westerly heading. Almost immediately, when the skids were beyond the edge of the plateau, the nose dropped, the aircraft lost height, yawed and drifted to starboard striking the pine trees and crashed. The passenger survived but the pilot died on his way to hospital. He died from a brain haemorrhage resulting from a fractured skull, the only serious injury he received. A severe degree of coronary artery disease was present which could be compatible with sudden incapacitation. He was not wearing a protective helmet, if he had done so he might well have survived. The pilot, aged 44, held a CPL for which he had his last license medical 4 months before the accident; an ECG performed on this occasion was normal.

Circumstantial evidence excluded pilot incapacitation as the surviving passenger reported the pilot had shouted: "There is something wrong with the controls", seconds before striking the trees; thus he was not incapacitated. The accident was survivable as the cabin showed little deformation and the decelerative forces were well within human tolerance.

Case No 2.

The pilot of a Citation 500 discontinued approach at night in poor weather and during the ensuing missed approach "go-around" manoeuvre the aircraft struck the roof of a house and crashed. The pilot, the only occupant, was killed. The cause of death was given as multiple injuries but at autopsy a severe degree of coronary artery disease was found in all the main coronary arteries. The Aircraft Accident Report (Department of Trade. 1982) concluded that the pilot failed to execute correctly a missed approach "go-around" manoeuvre, adding that the possibility of incapacitation perhaps in the form of an attack of angina, could not be ruled out. The pilot, aged 45, held a PPL with Night Rating and IMC rating, and had his last licence medical 3 months prior to the accident; an ECG performed at the time of examination was reported as being within normal limits.

Toxicology

Toxicological analysis of specimens from victims is an essential part of the medical investigation and should include examination for alcohol, the products of combustion and drugs.

In overshoot and undershoot accidents the wide bodied jets withstand impact forces well. The chances of survival are high with the important proviso that in the presence of a post crash fire the occupants can escape before being over come by smoke, fumes or heat. The DC10 accident at Malaga in September 1982 is a good example in which 330 escaped but many of the 55 fatalities in the rear of the aircraft died of asphyxia. Human tolerance to heat in post crash fire is a little short of 4 minutes in temperatures in the region of 200 degrees centigrade; however, the main hazards are smoke, lack of oxygen and toxic products of combustion, the single most important product being carbon monoxide. In an accident involving a Boeing 737 the accident investigators were seeking confirmation that there had been an in-flight fire before ground impact. The "event" leading to the suspected fire occured when the aircraft was at FL220. On-board there was a crew of 5 and 107 passengers. Autopsy examination showed clear evidence of an in-flight fire by demonstrating soot in 86 of 90 trachea examined. In all the blood specimens examined carbon monoxide levels were raised (average 42.9% saturation carboxyhaemoglobin); the raised levels of carbon monoxide could have lead to varying degrees of collapse, coma or even death (in case of highest levels) occuring in the occupants before impact. Evidence of burning was demonstrated in only 18 of 112 victims which suggested that flames were not a prominent feature of the fire. At the time of impact, 9 minutes after the "event", it is almost certain that all the occupants were unconscious; evidence from the cockpit voice recorder suggests that the captain was incapacitated just under 3 minutes after the event by which time the aircraft had descended to 13,500 feet.

Alcohol

Everyone is aware of the effects of moderate alcohol intake but the effects of small amounts are less well known. For example, at 50mg/100ml equivalent to one and a half pints of beer or 3 whiskeys, every person will show some impairment apparent as an increase in reaction time, impaired vision and coordination.

Billings et al (1973) set up an in-flight test to provide data concerning the role of alcohol as a causative or contributory factor in aircraft accidents. 16 instrument rated pilots flew instrument landing system (ILS) approaches at night in a

Cessna 172 while under the influence of 0, 40mg, 80mg and 120mg per 100 ml blood concentration of ethyl alcohol. Each subject conducted 2 flights monitored by a safety pilot who recorded procedural errors; during the flight each pilot carried out 4 ILS approaches landing after first and fourth and executing over-shooting procedures on the second and third approaches. The safety pilot had to take over control once during flights at 40mg, 3 times at 80mg and at the highest level pilots lost control of the aircraft 16 times in 30 flights. An important factor to emerge was that the authors were unable to determine a blood alcohol level that was not detrimental, and if any such level does exist it must be extremely low.

Aircraft accidents associated with alcohol can present investigators with high concentrations of alcohol where it has undoubtedly been the cause of the accident, as for example with the highest level recorded on our departmental files, namely 313mg/100ml. It is the levels between 50 and 150mg that present difficulty in interpretation in relation to accident causation particularly when there is an associated mechanical failure (Underwood Ground 1975), but there is usually an indication for the inclusion of a comment such as "the pilot's judgement and ability to maintain control was impaired by the amount of alcohol in his system".

Identification

The need for identification of victims of fatal aircraft accidents are not always fully appreciated. Some of the main reasons for identifying the victims of an aircraft accident are medico-legal for HM Coroner and insurance purposes, sociological for family and religious reasons and finally accident reconstruction. All available methods for identification should be used, checking one means against another, and ideally the aim should be to identify all the victims. Stevens (1970) states that the identification of the bodies of the victims of an aircraft accident is always a prerequisite for the determination of whether there is a main or contributory medical cause for the accident. He covers in great detail the types of evidence that may help to establish the identity of a body. If the bodies of passengers are individually identified and a passenger seating list exists, or if survivors can state where those killed had been sitting then much greater detail can be achieved in the reconstruction of the events (Mason and Tarlton 1969).

Full examination of clothing by the aviation pathologist is important. All clothing offers some protection against injuries particularly in the case of military flying clothing. Injuries to hands and feet will be reflected in gloves or boots and shoes.

Drugs

As far as the author is aware there has not been a single fatal aircraft accident investigated by the Department over the last 30 years in which drugs could have been a causative or contributory factor to an accident.

However, on a few occasions a variety of drugs—tranquilisers, hypnotics and analgesics—have been found among the personal effects of aircrew but in each case exhaustive toxicological analysis has failed to identify any of the drugs in tissue fluids from the owner of the drugs.

Nevertheless, the finding of the drugs in personal effects is important circumstantial evidence as it suggests that aircrew did not perhaps, enjoy the best of health. An entirely negative toxicological result merely indicates that none of the drugs were present in the body at the time of death; it does not exclude the possibility of drugs having been taken during a period of 24 to 48 hours or longer before death.

Survivability

An aircraft accident is survivable if the crash forces are within the limits of human tolerance and if the areas occupied by the occupants remain reasonably intact. Flailing of the body against injury producing structures is still the most critical determinant of injury and death which may or may not be associated with forces beyond human tolerance.

In survivable accidents death from drowning or from the products of combustion give rise to the all important question as to why the occupants failed to escape (Cullen 1973). This requires careful appraisal of the emergency exits, survival equipment (Balfour 1983) and the rescue services. In addition, the nature of impact injuries may give an indication as to why the occupants were incapacitated or entrapped thus preventing their escape. Mason (1970) conclusively describes how in an under-shoot accident which was manifestly survivable, 70 out of 81 persons in the passenger compartment died. In this crash 45 of 64 of the adult victims had sustained severe lacerations and fractures of the tibia and fibula from impaction of the legs beneath the seats in front leading to entrapment of the victims.

The Scene of the Accident

Experience gained in attending the accident site with the valuable briefing and demonstration of items of interest by the Accident Investigators will form a sound foundation for all the varying factors in subsequent accidents. Preservation of the scene and wreckage is of paramount importance and no examination of wreckage should be undertaken without the approval of the Investigator in-charge.

As no two accidents are the same, no rigid plan of action can be formulated to cover every investigation, but the experienced aviation pathologist will soon assess whether or not examination of wreckage is likely to assist him with the medical aspects of the investigation.

There are certain items in which the aviation pathologist has a special interest and he should, for example, examine passenger seats, lap belts and restraint harnesses of the aircrew. Fastened lap belts will usually lead to distinctive abrasions on the body, and, depending on degree of decelerative forces, intra-abdominal injuries. Thus the aviation pathologist may be able to match his post mortem findings with what he observes at the site.

Any aircraft accident investigation must clarify the question as to who was in actual control of the crashed aircraft, and to achieve this a visit to the scene is imperative and will assist the pathologist to interpret signficance of injuries. Examination of the control colomn in relation to hand injuries may yield valuable evidence in this respect. The area between thumb and index finger is subject to trauma if the control colomn is being held firmly by the pilot at the time of impact; it is injuries on the palmar surface of the hand which will be significant, whereas injuries on back of hands and fingers are usually the result of hands flailing leading to contact injuries.

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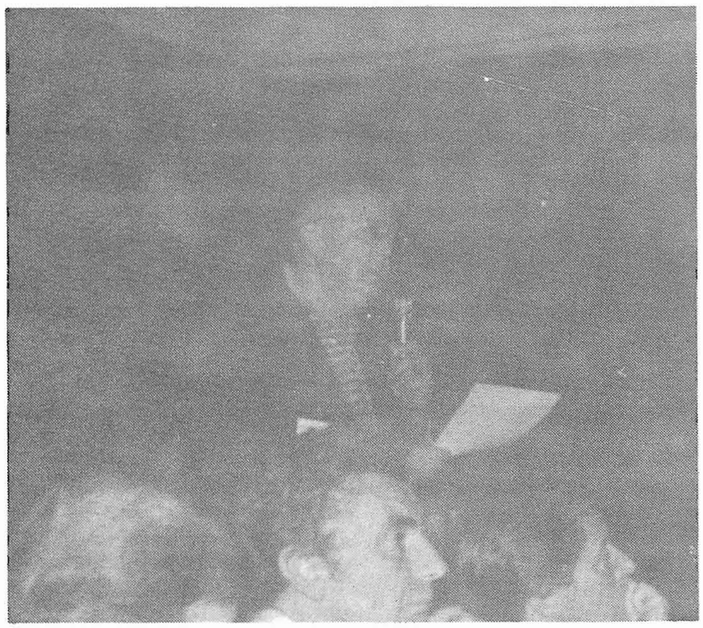
Ken Underwood Ground graduated from St. Mary's Hospital in 1941 and from 1942 to 1962 he was Senior Medical Officer in the Colonial Medical Service and served in Nigeria, Basutoland, Hong Kong and Uganda. Ken joined the RAF Medical Branch in 1962 and served until 1978. His present appointment is that of Civilian Medical Specialist in Aviation Pathology and Tropical Medicine at the RAF Institute of Pathology and Tropical Medicine. He works closely with AIB investigators into fatal accidents to civil aircraft. Dr. Underwood Ground has a number of publications in his name concerned with coronary heart and other pre-existing diseases encountered in fatal aircraft accidents.



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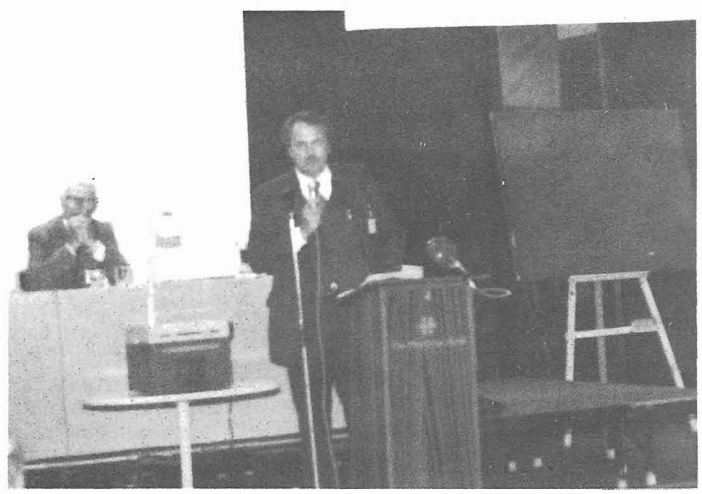
Bill Fromme, FAA



Ron Schleede, NTSB

Witnesses

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In the context of this paper the term witness is used to describe the initially uninvolved bystander who happens to be present at the scene of an accident. It is recognised that there are other kinds of witness as well as the happenstance observer but they are not the subject of this presentation. For example, there is the professional witness who may subsequently examine human or mechanical remains.

The casual witness may be anyone of either sex, any age or ability. The task facing the investigator is that what information the witness may possess will be "locked up" internally and of no potential value until it can be extracted and evaluated

There is no shortage of material about the value, or otherwise, of eyewitness evidence. It ranges from the ancedotal through the legal to the experimental. My own profession of psychology has been interested in the study of witness testimony since the turn of this century and from that time onwards there has been a fairly continuous programme of research and analysis.

The results of these studies confirm the position that the casual human observer can be unreliable and particularly unobservant. Moreover the process of extracting the information from the witness is a task which must be handled delicately.

In the context of aviation accident investigation I believe that it is important to recognise that the bulk of the studies of witness testimony have been undertaken against a legal background and in particular the administration of criminal justice. Consequently the objective of establishing guilt is never far from mind. In accident investigation, while blame may subsequently be assigned, the primary objective of establishing understanding can be kept more separate. This can have important benefits and permit a more flexible approach to data collection from witnesses.

The quality and accuracy of witness information can be influenced by:

The event

The perception of the event

The retention of the event

The communication of the event

Briefly I will identify some of the facts which affect the behaviour of the witness in each of these.

Event Factors

Duration: accidents happen quickly and the time span of occurrence may be very brief.

Complexity: allied with the speed with which an accident can take place is the number of elements which may comprise the event, their sequence and their prominence.

Salience: rarely does an imminent event announce itself as an accident about to happen. An accident may take the form of a number of apparently ordinary events which are suddenly disturbed by a number of unusual features combining to produce a catastrophic conclusion.

Ambient Conditions: accidents often happen in less than ideal operating conditions. Weather conditions, time of day, location, can all degrade the likelihood that a clear appreciation of the accident will be possible. In passing it is relevant to note that in accident situations where the weather conditions are particularly adverse the investigator may have to rely upon the evidence of an earwitness rather than an eyewitness.

Additionally, the witness may be in less than an ideal position to gain an accurate appreciation of events. Eric Newton, a well known British investigator, recounts in Barlay how a woman reported to the police that she had seen the aircraft wavering up and down violently prior to the crash. This report implied some control problem in the air prior to landing—an important lead in the investigation. The investigator found that her window faced the route taken by the incoming aircraft, and he knew that at that particular time there had been no other aircraft in the vicinity. To take a statement he sat in the armchair where she had been sitting knitting at the time of the accident. While she was describing what she had seen he heard the engines of another aircraft. He looked up just as the woman had done, and to his horror he saw another aircraft wavering up and down violently. There was a flaw in the window glass which gave the impression that all aircraft appeared to be out of control.

Perception Factors

Concomitant with the event factors are features which will influence the witness's ability to accurately perceive the events which take place.

Selectivity of Attention: Even under normal conditions we are not likely, or indeed able to, be aware of all that is taking place in and around us. An ordered pattern of selection takes place of the information received by the sensors and being processed by the brain. What determines which of the many imputs will consciously be perceived depands upon a number of factors. The most important are: perceived relevance of the event, previous experience of similar situations and the intensity of the stimulation.

Capability: While endowed with senses which can receive a wide range of physical and chemical stimuli, the human being is limited in his ability to make certain judgements based on these imputs. These can be categorised in relation to accident investigation as easy and difficult witness recall elements. For example, features such as aircraft, configuration, colour and direction of flight may be accurately reported, while estimates of height, speed and time duration are likely to be less accurate.

A second factor which can influence the performance of the witness is physical condition. The individual may be sick, or tired, and therefore not able to perceive clearly. He may simply lack necessary facilities to witness some aspect of the accident. Such sources of disability are loss of hearing and in some witnesses colour blindness.

Expectations: Reference was made above to the way in which selection takes place in the handling of the information. It is possible to demonstrate that in many situations we see the world not as it is but how we expect it to be.

This 'set' towards perception of events means that care has to be taken to distinguish between events perceived by the witness and the interpretation the witness places upon them. There is ample evidence that professional aviation witnesses on occasions do not report what they saw but what they believe was taking place. These features also have an association with the causes of accidents themselves. There have, for example, been a number of accidents to American school buses at railway crossings. The regulations demand that buses stop before proceeding across the rail crossing, the driver opens the doors and checks that the way is clear. If it is usual that no train is due at the time the bus arrives at the crossing, accidents have occurred when a delayed train is on the line and the driver apparently goes through the necessary procedures but still drives the bus into the path of the train.

Individual Differences: The same scene perceived by different observers can lead them to perceive different elements depending upon their own interests and attitudes. A potential accident situation may have a number of witnesses present, but some may take no interest whatsoever in a passing aeroplane while others may do so.

The Effect of Stress: Under stressful circumstances an individual's perceptions can be changed. The idea of the inverted U-shaped response curve remains the widely accepted representation of what can happen. A limited degree of stress may sharpen perception whereas extreme stress can reduce the overall quality of response. In terms of witness performance, the extreme effect of stress has been most effectively looked at in relation to witnesses of crimes of violence, where the focus of attention becomes concentrated upon the nature of the threat. The witness may be able to describe in great detail the fact that the assailant was holding a gun or a knife but was unable to give any great description of physical features of the assailant himself. Similarly, in relation to accident situations, it is possible for the witness to be concerned by the fact that there were flames present and the aircraft was on fire, but unable to give an accurate description of the flight path the aircraft followed while it was on fire.

Retention Factors

Having taken in information, time will take a hand in moulding the memory of the event. What is known about human memory indicates that the process of storing information cannot be likened to recording material on video tape.

Decay: Put simply, the more time that elapses since the inception of an event, the poorer a person's memory is likely to be of that event.

In Filling: A unique feature of human memory is that we like to retain cohesive and complete recollections of events. As a consequence there is a tendency to forge links in memory in order to retain a complete chain of events. If there are gaps in the sequence logical links will be created.

Post Event Enhancement: After having seen an accident there will be the opportunity to talk about the event with others. Ideas and events not perceived directly by the individual can unwittingly be picked up secondhand and incorporated into the witness's own 'recollections' of the event.

False Confidence: Recall of the event in memory, and its retelling to others can lead to a gain in confidence in the accuracy of the recollections. This can be of critical importance, for example, in legal circles where the value of a witnesses testimony is frequently judged by the degree of confidence the witness has in the testimony. There may be no relationship between accuracy and confidence.[7]

Communication Factors

Having found a witness who may have information, the task facing the investigator is to draw upon a strategy for accurately and effectively extracting the information held by the witness in memory. Until memories of the event are externalised and recorded they cannot be evaluated or used as constructive information which can be drawn upon in deciding upon a strategy for investigating the accident further.

Adequate Resources: Communication is dependant upon the ability of the individual to be able to externalise and describe events he can recall. Reliance may be upon the spoken word, with the investigator asking questions and the witness responding. The effectiveness of this process is dependant upon the level of literacy and quality of expression which the individuals possess. We have all on occasions used the phrase 'being lost for words' to describe a particular situation and in some situations the witness may find it impossible to put into words an accurate description of the perceptions of the event that held in memory. Moreover on occasions, if undue emphasis is placed upon requiring the individual to report in this fashion, it is possible for distortion of the information to take place as the individual will modify the events to match a verbal description. It is for this reason that in training accident investigators, emphasis should be placed upon the use of drawings, models, site visits and other means of eliciting the recollections of the witness.

Retrieval: The investigator/witness situation is one which on the face of it looks a simple interpersonal encounter but it has within it all the makings for potential conflicts in communication. In order to avoid this attention has to be given to: the objective of the interview procedure, the atmosphere in which the interview is to be conducted and the relationship which has to be established between witness and investigator. These features all stress the importance of treating the witness interview as an event which must be planned carefully.

Desire to Please: The one danger which exists within communication between the witness and the invetigator is the problem of objectivity. If good relations are established they can lead to a situation where the interviewees will feel it is their duty to provide the information that the investigator so earnestly requires. Under these conditions the danger of invention and fabrication is present. Evidence for this is available and there are a number of studies where fictitious events are created and witnesses subsequently come forward who are willing to swear that 'they were there'. Buckout recounts one such study by a journalist who fabricated a human interest story of how a lady got stuck to a newly painted toilet seat in a small town in the US. Having got the story distributed nationally, he visited the town and was able to make contact with a number of citizens all of whom claimed to have known the woman and to have played some part in bringing about her release from the embarrassing situation. In some situations such as this the desire to please has additional elements: for example a witness may come forward in order to maintain status within the community as well as to offer assistance to the investigator.

Sensitivity to Suggestion: In the interview situation there is the problem of the witness responding along the lines hinted at inadvertantly by the investigator. In legal terms, the 'leading question' has to be challenged in a court of law, but in person to person interview conditions there may be no-one present to identify that the information given by the interviewee was elicited in response to a heavily biased suggestion on the part of the interviewer.

Despite the shortcomings outlined in relation to the various stages of gathering, interpreting, storing and communicating information, there is no question that what the eyewitness says can have an important part to play in accident investigation. The task is that of identifying the most effective methods of obtaining information which is an accurate as possible. It is here that knowledge gained from experimental studies of memory, suggestion, performance of groups and simulations of accidents, for the study of witnesses, has value.

However, aiming for closer control of witness behaviour has to be tempered with realism, for some elements of the above sequence are beyond our control and manipulation. Improving the witness's likelihood of seeing the important events constituting an accident is not possible in the majority of cases. We cannot anticipate who will be a witness to an accident yet to happen. There are perhaps some circumstances where preparation is feasible. For example, training airport employees how to act if they are witnesses to an accident. Having been present at an accident is it possible to control the witnesses internal retention of experiences witnessed? This is difficult, though if early identification of witnesses can take place it is possible to initiate the information-gathering sequence in advance of decay and distortion occurring.

The most productive direction for the application of new techniques is in relation to evidence taking and recording. The methods of structuring the information-gathering process and of providing prompts for eliciting information have been the subject of a number of experimental studies. Some of these are providing interesting guidelines for devising and applying new approaches to the accumulation and documentation of witness evidence.

Four such areas of investigation are:

Group v. Individual Witness Reporting Perhaps because of the influence of legal requirements concerning the originality of evidence it has been the policy to keep witnesses apart and to take note only of individual responses. Work has been progressing to investigate what happens when witnesses are allowed to discuss the accident and then produce an agreed group report.

Structured v. Unstructured Reporting How a witness relates his experience can have an effect on the information obtained. Frequently the witness is first asked to recount the events in his own words. This is followed by a session of questions and answers between investigator and witness. An alternative is to first give a witness a structured questionnaire to complete which prompts him to give answers to specific topics.

Coherent v. Random Data Collection The witness is more usually asked to recall events in the form of a forward chaining sequence, i.e., from first sight of the aircraft through to its subsequent crash. There are alternative methods, two of which are the use of a backward chaining or deliberately randomising the order in which information is gathered so that the sequence of events is broken.

Confidence and Accuracy of Recall This paper touched earlier upon the somewhat unreliable relationship between the witness's confidence in his recall of the event and the accuracy of the event. How these two elements influence one another is a subject of growing importance. Again, this is an element which has arisen initially from the field of criminal evidence where one accepted criteria of the value of witnesses statements is the degree of personal confidence expressed in the accuracy of the evidence.

"Witnesses," Dr. Bekerian and Dr. Rolfe

Investigator Training

by
A. F. Taylor
Cranfield Institute of Technology

Introduction

In 1976 the AIB (Accidents Investigation Branch of the Department of Trade, now Transport) approached Cranfield with the suggestion that we should put on, with the AIB's help, a course to train overseas aircraft accident investigators. As we were already closely involved in design, manufacture, operations and safety this suggestions was welcomed and the first course was run in 1977 with 21 students from 18 different countries. Since then we have averaged 20 per course and have had over 50 countries represented at least once. We started out in 1977 with a course lasting ten weeks, shortened it to eight in 1978 and again to seven weeks for 1984. There is therefore a reasonable amount of time available for practical exercises to supplement lectures, films and discussion and these exercises have been steadily increased in number and/or scope as the course has developed.

Apart from perhaps a greater emphasis on the international nature of air transport and consequently of accident investigation, as befits a course drawing students from all over the world, our lecture programme is probably broadly similar to other such courses. I therefore intend to concentrate in this paper on the practical exercises.

Our intention has always been to provide the students with practice in the procedures followed when interviewing witnesses and when examining wreckage together with an opportunity to gain experience in managing an accident investigation. Thus about half way through the course we stage an 'incident' with one of our College aircraft in full view of half of our course. They thus become eye witnesses for the remainder of the course to interview. In fact the whole course is given the opportunity to practice interviewing as the other half witness an accident on film. The 1977 and 1978 incidents have been described in detail by Taylor (1979) in the College of Aeronautics magazine 'Aerogram' however a brief description is appropriate here.

The Witness/Interviewing Exercise

On one such occasion I led a group of about 10 students across the apron to rendez-vous with a colleague who was to show them our College Jetstream 'flying laboratory' aircraft and the work currently in hand within our Flight Hangar, an area usually out of bounds to all students. On the way we passed our own designed and manufactured competition aerobatic aircraft, the Cranfield A1, and a light twin which was in the process of being refuelled. When we stopped at the corner of the hangar in a position next to one of our Jetstreams and with a good view of the other aircraft and of the airfield I went inside to find my colleague. Meanwhile the refuelling vehicle crossed the apron and began to refuel the Jetstream, two people emerged from the hangar, did a perfunctory preflight check of the light twin, got in, started up and taxied past the waiting group. Eventually it took off but on climb out there were coughs and splutters and considerable yawing and rolling followed by an immediate circuit and landing on one engine with a rapid and noisy turn out of the fire service vehicles.

After the aircraft had stopped on the runway surrounded by the fire section I pointed out that they had witnessed an incident and asked them each to write an account of what they had seen and heard since leaving the lecture room. Although several of the accounts of the aircraft's manoeuvres after take off were very accurate no one noticed that the aircraft, a piston engined twin, had been filled with aviation kerosene while they had been standing nearby. Remember that the bowser, clearly labelled 'Avtur Jet A1' had subsequently parked right next to us to refuel the turboprop Jetstream. To my eternal shame neither did I notice! My 'excuse' was that on all previous occasions we had used a Jetstream for the incident so I had total tunnel vision and saw only the Jetstream. One student subsequently admitted that he had noticed something strange but as no one else had taken any notice he had assumed all was well and didn't say any thing at the time neither did he report it to his interviewer as by then he had forgotten its possible significance.

Of course we hadn't actually put kerosene into the twin as on all such occasions we take all possible precautions to avoid having a real incident.

On other occasions we have used a very much shorter scenario such as a near collision between two aircraft and between an aircraft and a ground vehicle. With these we try to make sure that everyone is facing the right way, otherwise perhaps no one would see the incident at all which would waste the considerable number of manhours spent in staging the incident.

The Four Day Exercise

Near the end of the course we stage a full accident to a light aircraft using our Air Traffic Control, Fire Service and many local inhabitants as witnesses and this time of course the investigators have to examine the (carefully prepared) wreckage as well and conclude the exercise by preparing a complete aircraft accident report. This four day accident investigation exercise and several subsequent ones have also been described by Taylor (1977, 1979 & 1981) in 'Aerogram', they have all been highly successful, that is to say both instructive and enjoyable, due more than anything to the painstaking preparation of witness briefings, wreckage, ground marks and documentation by members of the Accidents Investigation Branch.

In view of the number of people involved we are obliged to divide the course into three teams. Each is invited to choose its own leader, or investigator-in-charge, each can delegate particular tasks to their engineers or pilots. The only real constraint is that time on the accident site itself is limited so that each team is totally independent and so that the directing staff can reassemble the wreckage to the same state for each team before each site visit.

Our very first 'accident' occurred on 21 June 1977 at about 0930hrs. Several people saw some part of the flight leading up to the crash including Air Traffic Control. Others had seen one of the two on board in a pub the previous evening or limping out to the aircraft with his pupil prior to the flight. The Fire Service were promptly on the scene and, apart from helping the ambulance drive to extricate the badly injured occupants, they were obliged to cover with foam a considerable area of spilled fuel, along with certain items in the wreckage trail that might have helped explain the accident. Of course the teams of investigators didn't know any of this until they 'arrived' at Cranfield airfield and began tracking down the witnesses, sorting our their stories and following up vital clues. What emerged fairly quickly was that the aircraft had been taking off with an experienced instructor and a pupil who was later found to be very inexperienced when, at about 200ft to 300ft the engine was heard to be losing power and seen to be emitting black smoke. What puzzled the investigators was not only why the engine should have lost power but why an experienced pilot should have attempted a steep right hand turn to land downwind rather than put the aircraft down straight ahead on the remaining runway.

An examination of the engine showed the fuel supply to be in order; the fuel cock had evidently been closed only seconds before impact, but the plugs were all well sooted confirming suspicions aroused by the black smoke of an overrich mixture. The air filter was found back along the wreckage trail and was well bent and full of earth and grass. However, when this was removed a few feathers could be seen, but these were dismissed by one team as being from the instructor's feather cushion that had burst on impact. A re-examination showed them to be quite different feathers and an extensive search revealed that a dead pigeon had laid hidden in the long grass close to the aircraft for a couple of days. The engine failure was explained but not the crash.

While the engineers had been busy on site, other team members had discovered a crucial witness who had unfortunately not been available for interview on the day of the crash. He had seen something fall from the aircraft and, although a careful check had already been made of the aircraft and no parts had been found to be missing, a further search was made; in fact, the receipt of a supplementary report from the pathologst who now stated that the instructor had bled extensively before the impact sent one team running onto the airfield as they had already been thinking of a birdstrike on the windscreen.

Sure enough, out near the runway were found a part of the windscreen and a dead pigeon, and a further search of the interior of the aircraft uncovered pieces of windscreen with blood on them and also, in amongst the cushion feathers, a couple of flight feathers from a pigeon! The reconstruction, jigsaw fashion, of the windscreen showed exactly where the bloodstained pieces and the piece that fell came from—straight in front of the unfortunate instructor. Under the circumstances, it was not altogether surprising that the pupil, with only about an hour flying behind him, couldn't cope.

More recently we have used an Aztec, which is perhaps the ideal size and complexity for such an exercise. Usually the flight crew, and often the investigators, have had some difficulty in identifying which engine has malfunctioned!

Naturally each subsequent 'accident', even when using the same wreckage in more or less the same position (this being dictated by the nature of the aircraft's real crash), has had a totally different set of contributory factors. What they all have in common is variety in the sense that in order to put together the complete story the investigators cannot afford to overlook any aspect of the investigation.

The 'Look at and Record' Exercise

When, after three 'accidents' to the same Cherokee aircraft we purchased a new wreck, we were able to introduce an additional 'look at and record' exercise using the original wreck. This we realised was necessary when we observed the reactions of people on arriving at their first accident site. The careful, methodical approach described in lectures was forgotten as, when faced with the daunting task of finding the equivalent of a needle in a haystack, many of them moved things before photographing, trampled on ground marks, made wild guesses or simply gave up. These tend to be first time only reactions so now, having had a chance to look at and record everything they can during this short exercise, without having to draw any conclusions about cause, they are all much better organised when they reach the site of our main four day exercise.

What also became clear after a few of the four day exercises was that some teams were being handicapped by a lack of effective internal management, perhaps by an inability to delegate or by losing control or by failing to spot the need for certain information or by not using it when it was available. It was for gaining prior experience of this kind of problem that the management simulation 'In the Hot Seat' was designed. Our first attempt was put together at Loughborough University's Simulation—Games Development Workshop in March/April 1982, this was tried out on two recent AIB recruits during the 1982 course. The first full scale version was run during the 1983 course and is described by Rolfe and Taylor (1983) in Sagset proceedings. Numerous improvements are still being made.

The Management Exercise

Most accident investigations will call on the skills of a number of experts to solve a complex puzzle for which there may be, in the end, no discernible solution or, equally likely, there may be a chain of identifiable occurrences which combined in a unique manner to result in the accident. While the aim of a genuine investigation will be the search for a solution to the accident it will not be the only problem facing the investigators. The investigating team may not have worked together before (some of the members may be foreign nationals

Our first *Cherokee* during the main exercise in 1978.

representing the country of origin of the aircraft and its crew), and they will have to become a cohesive group very quickly with each member assuming particular responsibilities and ensuring that his colleagues are kept informed as information becomes available. There will be a problem over time. Most likely a deadline will exist by which point a solution will be expected but also some factors in the investigation will be transient and if not attended to by a certain time the information may be lost completely. The investigation will not be a private affair. The accident is likely to have created national and local interest so that the investigating team will find itself under pressure from politicians, the news media and local pressure groups.

These then were some of the features we considered important to expose students to when teaching them to manage an accident investigation. To this end we set out to design 'In the Hot Seat' an accident investigation management simulation (AIMS) procedure. The exercise simulates the conditions encountered during the early stages of an accident investigation. It attempts to give experience of managing the investigation process to a point where the initial analysis has been successfully completed and it concludes with the submission of a report outlining the circumstances of the accident, the likely causes and the further detailed analyses which have been initiated.

For the simulation we selected an accident, added some elements from other accidents, and altered, where necessary, those features which would identify actual people, places or equipment. Some invention was necessary to create additional relevant information which had been removed from the records of the actual investigation by the diligence of the investigators. We chose an accident for which a definite set of causes could be established but which was complicated in that it was an accident which was attributable to a number of factors; however the aircraft type is an invention and, in particular, the country in which the accident occurs, Kronenbourg, would be difficult to find on most maps!

As noted above one object of the simulation was to make students aware of the importance of identifying information required and initiating action to obtain this information. In this context one aspect of the simulation which is important is the presence of realistic delays between the request for information and its receipt. In an actual accident investigation such delays can run from hours to days depending upon the complexity of the information required. We drew upon existing information from the actual records to determine how long it takes to obtain particular information and we then scaled these times down to the playing time available for the simulation.

For the simulation we divided the students on the accident investigation course into teams of six or seven each having a specific role. A brief on the Directorate of Aviation is inset and a typical team would include the Deputy Director, those beneath him, a PRO and perhaps two foreign nationals. Each student has his own particular role and his own brief. Thus each knows all that is necessary about himself plus a little about the others. All will know something about their own country and perhaps something about any other country involved. Some will know something about the aircraft and/or the pilot. Each team has one additional member who is played by one of the directing staff. This invisible team member has access to the crash site, to the wreckage and to some of the witnesses, he reports his findings to the rest of the team. During the 1983 and 1984 simulations this staff role was the Assistant Director (Operations).

Each team has an office and a telephone and while the bulk of routine contact with the staff directing the simulation is by telephone, personal encounters do take place. These take the form of interviews with the Director of Aviation, press conferences, television appearances and chance encounters with members of the general public. The directing staff role play parts in these personal encounters. Some additional realism is encountered as telephone contacts with the directing staff are limited by the number of lines available and consequently teams may find the number they wish to contact is engaged, thus causing additional frustrations and delays.

The directing staff for the simulation is made up of a professional accident investigator, an aircraft engineer and a psychologist. Both the latter have experience of accident investigation procedures. In addition, there are three secretaries to log incoming calls, handle information files and role play.

Our second *Cherokee* in 1980. This is now used for our "Look at and record" exercise. Note ISASI member 2332 on the left!

***Aztec G-BBOJ* during the main exercise in 1982. This aircraft is still in use.**

We do not see the simulation as it is at the moment completed or totally satisfactory. It is designed to be flexible and modifications are being made. In the long term our aims are to develop a core structure for the simulation which will allow us to run different accident scenarios using the same procedure. One thing we have learned is that speed and load stress may not always be upon the student and at times it is the directing staff who may suffer. To help here we are considering making use of a microcomputer to handle the scheduling of information to the different teams taking part in the simulation and to log the progress of the simulation. This will also make the simulation readily portable.

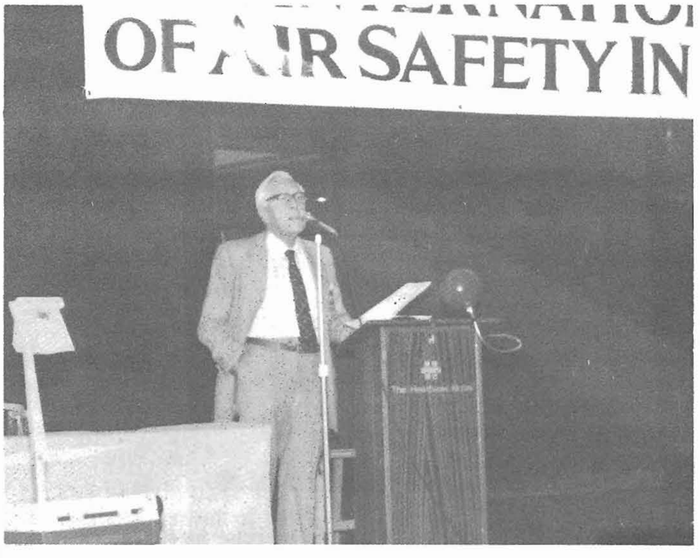
When the simulation was first run at Cranfield, it filled one afternoon and an evening. However, this was inadequate so for 1984 this was extended to an evening briefing plus a whole day for the exercise and a debriefing the following morning.

Conclusions

We now feel that our three preliminary exercises, 'Look at and Record', 'Witness/Interviewing' and 'Management' together with all the supporting lectures and discussion, give a most valuable base for tackling the main four day exercise. Consequently we believe that the whole course meets its principle objective which is to provide students with a sound basic knowledge of the requirements, procedures and techniques associated with accident investigation and prevention.

Postscript

Due to circumstances which we hope appeared beyond our control but which were in fact carefully planned, only part of this paper was actually presented. An account of these circumstances and of the subsequent findings appears elsewhere in these proceedings.

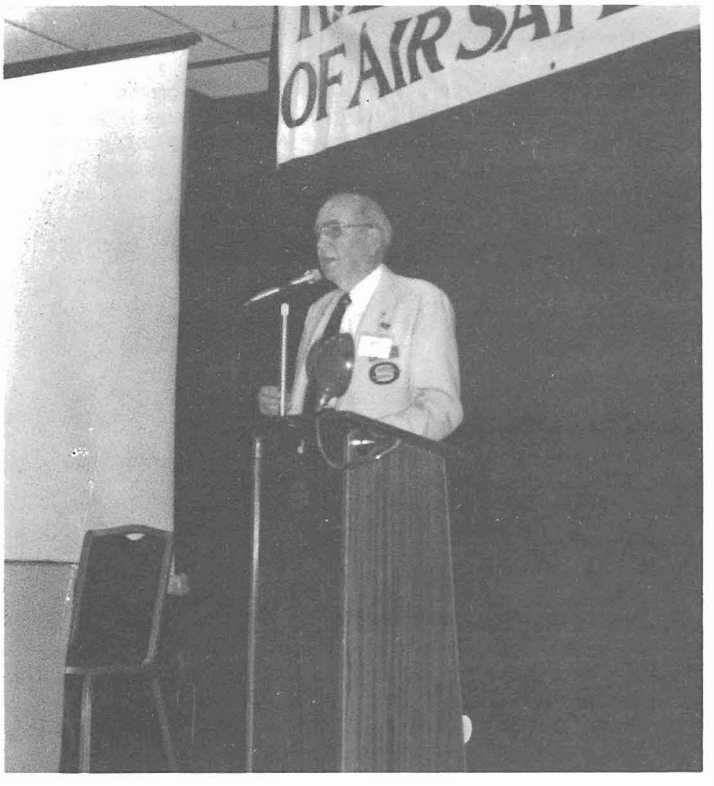


Laurie Edwards, Seminar Committee Chairman

THE AUTHOR

A. FRANK TAYLOR

Frank Taylor has been a Cranfield Lecturer since 1967, Senior Lecturer - Design and Safety of Aircraft Systems since 1979. His main subjects are aviation fuels, aircraft fuel systems and associated fire risks; environmental control systems; fluid mechanics of aircraft systems; safety and accident investigation with particular interest in crashworthiness and survival.



John McDonald, President, at the podium speaking before the General Membership

Confidential Human Factors Reporting Programme

Roger Green, BSc, MRAeS
Head of Flight Skills Department
RAF Institute of Aviation Medicine

Introduction

The UK Confidential Human Factors Reporting Programme (CHIRP) was instituted in December 1982 as a result of a study carried out by a working party chaired by the Chief Scientist of the CAA. After studying the results of incident reporting schemes around the world, this working party decided that a UK scheme should be established which would enable commercial flight deck crews to report, confidentially, the details of any incident in which they were involved if they felt that the incident, however trivial, had any implications whatever for flight safety.

As such a sheme would rely for success on the confidence of crews, the CAA sought a disinterested party to operate it and it was agreed that the RAF Institute of Aviation Medicine possessed the required attributes. However, before the scheme was launched a good deal of discussion took place about its terms of reference and, in particular, about the legal implications of its operation, for all incidents should, mandatorily, be reported to the pre-existing CAA occurrence reporting scheme. Not only did the CAA decide that it would not let this requirement impair the operation of the new scheme, but it agreed that it would not prosecute offenders of the Air Navigation Order who reported their misdeeds to CHIRP provided that:

i) any infringement was neither wilful nor grossly negligent.
ii) any infringement was directly connected with the Human Factors Incident reported.
iii) the person concerned forwarded a completed CHIRP form within ten days of the incident.

Inception and Operation

To launch the scheme, all holders of a UK licence to operate aircraft for commercial purposes (this included Pilots, Flight Engineers and Flight Navigators) were sent an introductory note, a report form and a prepaid envelope. Further sets of forms were sent to most airlines in the UK, and many of these airlines were visited in order to explain to them the aims and operation of the scheme.

The report form is designed in three sections for i) the reporter's name and address, ii) details of aircraft type, time of occurrence, etc., and iii) a narrative of the event. When a report arrives at the IAM (via the Post Office's Freepost scheme) it is opened by one of the team members (Green, Skinner and Wilson) who detach the first part of the form and return it to the reporter once they are satisfied that no further information is required. The reports are then disidentified, by removing any revealing details of times and places, and filed on the IAM's main computer, access to the CHIRP files being only by password. As soon as it is possible to produce hard copy of a number of disidentified reports these are passed on to the CAA Safety Data and Analysis Unit. Thus, no records of names and addresses are kept in any location and no material is available which would enable any event to be identified.

The principal use to which the IAM is required to put reports is in the production of FEEDBACK, which contains a digest of twenty or so reports edited at the IAM, printed by the CAA, and distributed to all licensed crews. Given the minimal staffing of the scheme, this is a major, fairly costly, and time consuming exercise even though FEEDBACK is produced at only four monthly intervals. It is strongly felt by the IAM, however, that FEEDBACK is an essential ingredient of the scheme in that it does serve to "feed back" genuinely useful information to crews, to maintain an awareness of CHIRP in the industry, and to act as a stimulus for new reports.

Reports

Numbers

During the first year of operation, i.e., between December 1982 and the end of November 1983, 241 reports were received and at the time of writing (July 1984) this number has increased to 354. This obviously represents a response rate of about one report per working day, but the distribution of these reports was not even through the year, their receipt being concentrated into four periods. The first of these followed the launch of the scheme, and the subsequent three following the distribution of FEEDBACKs. It does not appear from the contents of reports, however, that specific items in FEEDBACK stimulated more reports about the issue involved, but that the arrival of FEEDBACK acted as a general stimulus for the recipient to overcome the inertia involved in putting pen to paper. It is therefore believed that FEEDBACK must remain an important element of the scheme.

Although it is tempting to compare the rate of response to CHIRP and other schemes and to use this as a measure of success, it is very difficult to do so as the only available comparable programme is the US ASRS (Aviation Safety Reporting System) and there are many differences between the schemes despite their superficial similarity. For example, ASRS receives air-miss reports, military reports, ATC reports, and there are much more pressing legal reasons for a US pilot to report to ASRS than there are for a UK pilot to report to CHIRP. The important comparative point here is that UK reporting procedures are much more fragmented than in the

USA. It is almost certainly not in the interests of safety for them to be so, but discussion of rationalisation is beyond the scope of this paper. Before leaving the question of reporting rate, however, it is interesting to note that during 1983 about 1 in 30 of all active UK commercial pilots submitted a CHIRP report.

Contents

The subjects addressed by the reports received at the IAM vary widely but a representative sample of reports has been included in the FEEDBACKs and these are available. In order to enable reports on a given subject to be extracted from the computer data base, a "key words" system is being developed which enables a report to be searched for in terms of any of the data items given in the middle section of the report form, or any of a set of key words which are appended to the report by a member of the team.

It is probably premature to attempt any rigorous analysis of the reports with the present numbers available, and with the present experience of the team. Nevetheless, certain dominant themes are apparent and these are now discussed briefly.

i) Sleep, Fatigue, and Rostering.

Fifty-two of the reports so far received cite problems of sleep, fatigue, and rostering. The most dramatic are those in which the reporter has actually fallen asleep in the aircraft, and such reports have arrived from crews crossing the Atlantic (e.g. FEEDBACK 2, p. 3), from helicopter crews on the North Sea (e.g. FEEDBACK 1, p. 3), and from solo air taxi pilots (e.g. FEEDBACK 2, p. 3). There can be no real doubt that such documentary evidence of what is obviously an enormously serious problem would not have become available if CHIRP did not exist.

Reports have also been received from crews who did not actually fall asleep, but who felt that their performance was degraded by fatigue, and many of these reports have blamed present flight time limitations and rostering problems (e.g. FEEDBACK 3, p. 5).

ii) Crew Interaction

Problems between individuals on the flight deck have been cited in 46 of the reports so far received. These are particularly difficult to deal with as there is no obvious action which can be taken, save to draw the issue to the attention of other crews via FEEDBACK. However, these reports differ from those in which a pilot is reporting his own error in that a third party may read the published report and feel that he is being blamed, unjustifiably, for an incident. Despite this, a number of such reports have been included in FEEDBACK (No 3, p. 2) and it is felt that such material is of great long term value (e.g. in the development of "Line orientated flying training" exercises) even if immediate remedial action is impossible.

iii) Ergonomics and the Inappropriate Execution of Skills

A surprisingly large number of reports (79 to date) are of the form "I intended to do *x*, but without realising it, I did *y* instead," and of these, 60 reports cite a control being operated instead of the intended one rather than a confusion between procedures. Examples are given in all FEEDBACKs, in particular No 2, p. 4. No rigorous analysis of these reports has been carried out but it is clear, firstly, that these problems occur to experienced pilots who have carried out the intended actions many times, and make the correct decision, but execute the wrong action, and secondly, that the action which was executed usually has some attributes in common with the intended one. It is difficult to identify a route to curing the first of these factors but the second certainly involves ergonimic inadequacies which should be capable of amelioration. For example, a number of reports have identified that BAC 111 pilots can easily switch off LP fuel cocks when they were intending to carry out another action. The solution will clearly involve a design modification, and one report contained a practical and possibly useful suggstion.

iv) Miscellaneous

From the numbers given above, it can be seen that the three categories of report already described account for more than half of all those received. However, some themes on which a number of reports may have been expected have not, in the event, generated many. For example, illusions—though being quoted as a causal factor in many accidents—have been cited as a main factor only once (FEEDBACK 1, p. 4 "jet transport"). Again, the problem of domestic stress has appeared as a main factor in a report only once (FEEDBACK 1, p. 7), although this single report is most dramatic and potentially valuable. Disorientation has been cited most infrequently (e.g. FEEDBACK 1, p. 6) though again in a most dramatic way, and the same can be said for in-flight incapacitation (FEEDBACK 2, p. 7).

There are some obvious small groupings within these miscellaneous reports (for example, reports which describe why de-icing was not properly carried out on the ground, leading to difficulty in the air—FEEDBACK 3, p. 6) but a rigorous analysis of these, and in fact all, reports relies on the development of an effective keywords system for their retrieval. As noted above such a keywords systems is already in operation in a limited form and a fully flexible version should be implemented on the IAM computer database in the very near future.

Actions

In addition to passing disidentified reports to the SDAU at Redhill, other actions have been taken when they have appeared appropriate. A conspicuous example was as a result of a report received which described how a Boeing 737 has been de-fuelled by engineers and left with the start levers in an inappropriate position for engine start. The pre-start check list did not enable the unusual configuration to be detected, and as a result, the engine was nearly wrecked during the start sequence. All UK operators of the type were informed of the problem by telephone as de-fuelling was a prevalent event at the time of the report.

Several other single reports have identified specific problems on which it has been felt that action was necessary. For example, an excellent submission detailed how a Boeing 747 took off in poor weather with no pitot heaters switched on (FEEDBACK 2, p. 2). This event was immediately reported to the UK operators and modification action has been taken. It may be noted, parenthetically, that this even is exactly the type of problem with which CHIRP copes well. The pilot was reluctant to admit what could appear a gross failing to his company, but was happy to do so to CHIRP; aviation safety has been improved conspicuously as a result. An analogous situation prevails with the procedure for fuel cock operation in the BAC 111. These incidents were all passed on to the manufacturer, who welcomed them and who has taken positive action as a result.

The Future

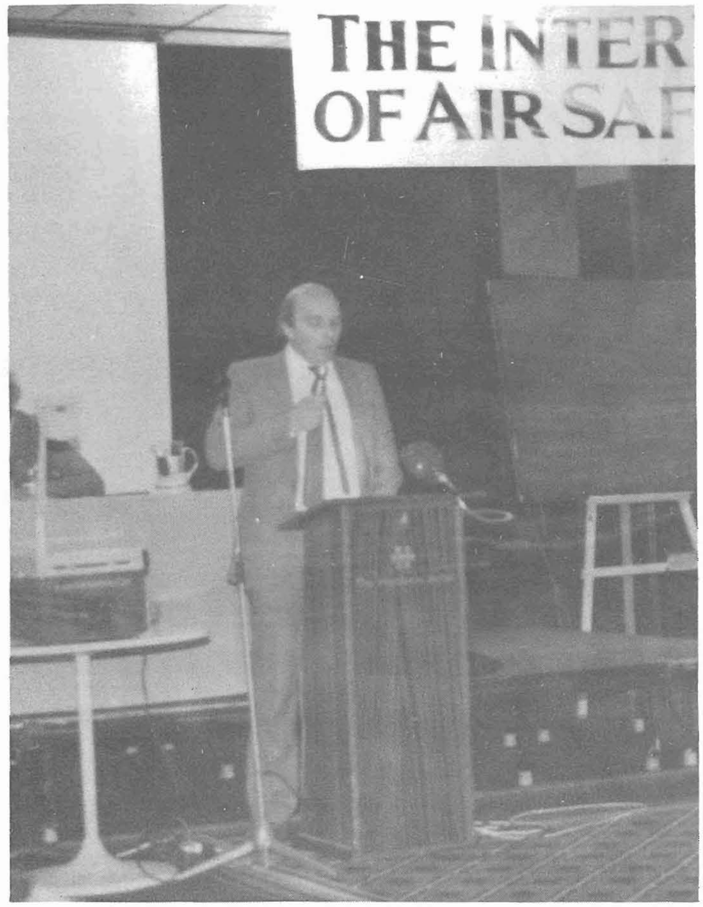
The progress of CHIRP will be reviewed by its sponsor—the CAA—after two years of operation (i.e., at the end of 1984) to determine whether its trial period has demonstrated the requirement for such a scheme and, if so, in what form.

It is felt by those of us who operate the scheme that it has both been well received by its "customers" (i.e., the UK commercial flight deck drews) and has been shown to fulfil a useful function. Indeed the only pressure that has been put on the scheme to change its scope has been in the direction of expansion. Air traffic controllers have frequently shown interest and lobbied for their inclusion, and enquiries have been received from several foreign flying organisations to have the scheme extended to them.

Although the future of CHIRP must await the decision of the CAA, it does seem that CHIRP, or something like it, has a valuable role to perform in aviation and is probably here to stay.

Roger Green BSc MRAeS
Head of Flight Skills Department,
RAF Institute of Aviation Medicine

Roger Green is a graduate in Experimental Psychology from the University of Sussex where he gained a first class honours degree. Since then he has been employed at the RAF Institute of Aviation Medicine where he is presently head of the Flight Skills Research Section. The activities of this section include research into the perceptual, social and stress problems associated with flight, as well as the provision of psychologists for attendance at RAF accident enquiries. The UK Confidential Human Factors Incident Reporting Programme has been operated since its inception within this section, and it is this scheme which is addressed in this ISASI presentation.



Rodger Green, RAF

The "Award" dinner Wednesday evening.

European Regional Society President and Seminar Chairman Laurie Edwards addresses the banquet participants.

The "head" table, (L-R) Rodger Smith, Ruth McDonald, Laurie Edwards, Lady Masefield, Sir Peter Masefield, Betty Edwards, Paul Choquenot and Margorie Smith.

Jerry Lederer

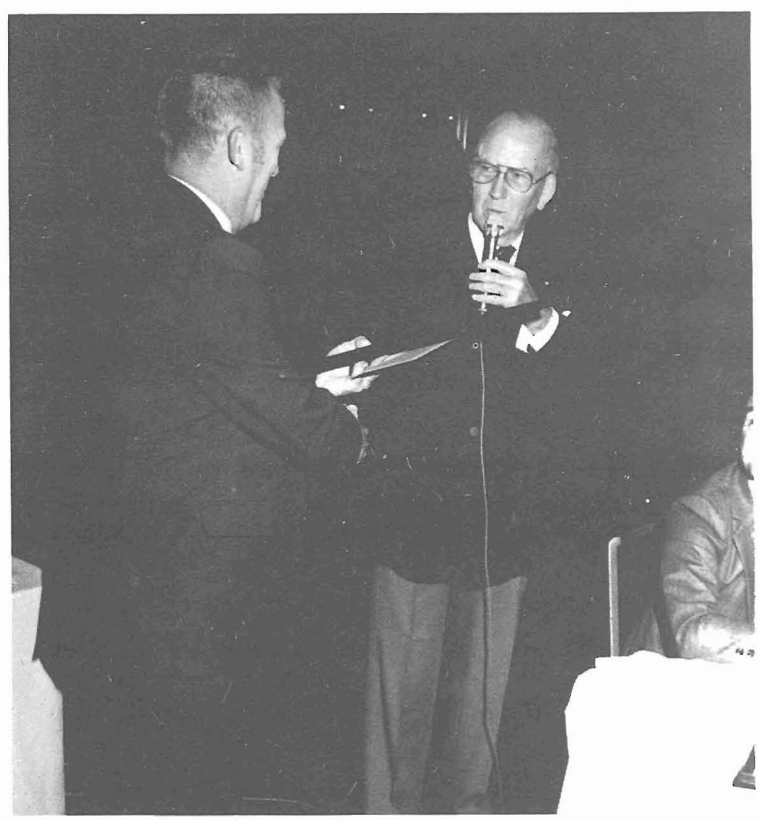
Jerry Lederer presents the Lederer Award to George "Skee" Parker.

George B. "Skee" Parker,
Jerome F. Lederer Award Recipient.

Laurie Edwards, ESASI President, receives European charter from ISASI President, John R. McDonald.

President McDonald presents charter to CSASI President, Rodger Smith.

Captain Dick Stone receives Southeastern Chapter charter.



Ed McNeil, President of the Northeast Regional Chapter, receives charter.

Ira Rimson, Mid-Atlantic Regional Chapter President receives charter.

Dick Baker, Treasurer of the Rocky Mountain Regional Chapter receives charter.

Captain Jack Jessup received British Airways' Corporate Member Plaque from President McDonald.

Sir Peter Masefield - Guest of Honor

The loyal toast "Her Majesty the Queen."

Laurie Edwards, ESASI President, with friends
Peter Marsh and Robert Gardner of B.A.E.

Peter Bardon, ESASI Vice President, with Bill and Margaret Tench and Ron and June Chippindale.

Laurie Shaw, ESASI Treasurer, Captain Jack Jessup, British Airways, and John and Ruth McDonald.

DEBATE
"This House Considers That Human Factors Investigation Is A Waste Of Time."

Chairman:
William H. Tench

Proposed by:
Peter Pardon, Deputy Chief Inspector of Accidents, AIB
and
Rodger Green, Head of Flight Skills Dept., RAF Institute of Aviation Medicine

Opposed by:
Ron Schleede, Chief, Human Performance Division, NTSB
and
Captain Dick Stone, Delta Airlines

A unique part of the technical program addressed the controversial subject of the human factors (human performance) investigation. Chaired excellently by Bill Tench, former Chief Inspector of Accidents, AIB, the debate raised some fundamental questions concerning this type of investigation.

The first spokesman, Peter Pardon, cited some "human factor" type accidents and incidents and raised the question on the appropriateness and adequacy of such an investigation. He asked, "What is a human factors accident?" and "Where does the operational investigation end and the human factors investigation begin?" It was his contention that a human factors investigation is not new. That, in Britain, such an investigation has always been performed as a part of the operational side of the accident inquiry. Mr. Green pursued the idea of how does the investigation authority handle sensitive human factors information and addressed the difficulty of taking preventive measures with respect to this type of information. He also asked "What role and responsibility does management play in a human factors accident investigation?"

Ron Schleede supported this type of investigation and described the Safety Board's multi-disciplinary approach to this type of investigation. He believed that the majority of accidents causes were directly related to human factors. He stressed the need for this discipline since the prevention of similar type accidents depended on identifying the underlying causes of certain accident enabling behavior. He raised the issue of the need for absolute proof versus reasonable belief in arriving at human factor conclusions.

Captain Dick Stone remarked that 60 to 80% of the accidents were related to pilot cause factors and this finding prompted ALPA in the early 1970s to investigate in an attempt to determine why pilots make errors. He stated, however, that the industry does not have a well organized plan for use in the human factors investigation. It was his opinion that this situation has resulted in a tendency to rely too much on psychologists for answers. He favored the multi-disciplinary approach to the human factors investigation which should conduct a reconstruction of the causal events starting at the accident site.

These discussions by the panel members were followed by questions and comments from the floor by those who took a position for and against the human factors investigation. There were several attempts by participants to define a human factors investigation. The bottom line resulting from the excellent discussion on this subject was agreement by both sides that the "human factors" investigation was an inseparable part of the multi-disciplinary process of the accident inquiry. However, it was obvious that there were various opinions about the process. The debate concluded with the following list of pertinent questions that were not answered satisfactorily during the discussions and should serve as a guideline for future discussions on this subject:

1. What is a human factors (human performance) accident investigation?

2. Who or what discipline is best qualified to perform the human performance investigation?

3. How should the human factors investigation be conducted?

4. To what extent or limits should the human factors investigation go?

5. What criteria is used to determine the relevancy of the human factors information to the cause of the accident?

The following definition of a human factors investigation was offered for membership consideration:

"The identification and the explanation of all acts of human performance failure or degradation by those persons associated with an aircraft flight which led to the adverse sequence of events resulting in an accident or incident."

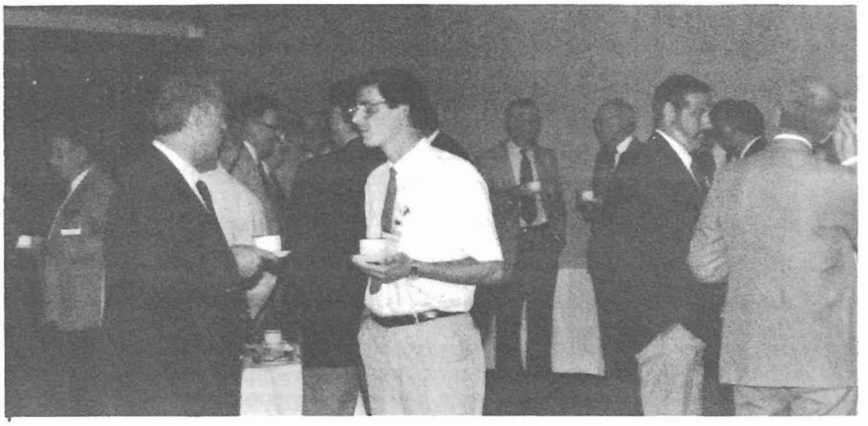
Jerry Lederer offered the following definition of "human factors:" "Intellectual, emotional, physical, psychological and managerial forces that govern mental and physical performance."

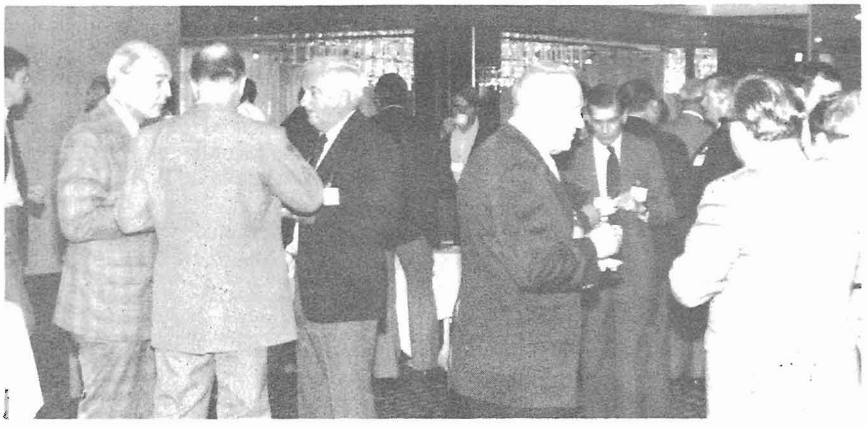
It is hoped that our membership and other readers will respond to these comments and questions so that a compilation of the responses could be published for future discussion and perhaps development of better human factor investigation guidelines.*

Editorial Staff

*We apologize for this brief summary of this most interesting debate, but a transcript or the tape recordings of the debate were not made available to the staff for preparing the text. In that regard, we hope that reconstruction of this summary from notes and memory is accurate and offer our apologies for any errors.

Coffee Break @ 1030





Composite Materials Failures

by Graham Dorey
RAE Farnborough Hampshire

Introduction

The drive towards the increased use of composite materials in aircraft structures comes from the limitations of existing materials and the constant need for improved performance and cost effectiveness. Advanced composte materials can be made from a variety of fibres and matrix materials, examples of which are listed in Figure 1. Carbon fibres are light, stiff and strong and are used for aerodynamic surfaces; and have potential uses in aircraft fuselages. Glass fibres are more compliant and find application in the dynamic components of helicopters. Aramid fibres have high specific tensile strength useful for pressure vessels, and they have good impact resistance for use in lightweight armour. Boron fibres are thicker (> 100 μm compared with < 10 um) and have greater stability in compression.

Matrices have been mainly thermosetting resins (chemically reacted), and epoxies have predominated in most aircraft structural applications, although for higher temperatures between 150° and 250°C polyimides are necessary. Thermoplastics, formed by a melt/solidify process offer improved toughness and manufacturing advantages of shorter process times and reprocessing capabilities.

Further advantages, from using advanced composites in aircraft structures are shown in Figure 2. Manufacturing advantages include the ability to mould complex shapes, with less material wastage and fewer parts for subsequent joining operations. The ability to mould complex shapes is also useful for repair procedures using the actual component as a mould. Because composite materials are anisotropic, laminates can be designed that couple bending and twisting, allowing the tailoring of aeroelastic deformations useful for improved efficiency and essential for new concepts such as the forward swept wing.

It is with carbon fibre composites that the greatest advances are being made and this paper concentrates on them. The main advantages are listed in Figure 3. A brief summary is given in Figure 4 of their development from the initial fibre manufacturing process developed at RAE in 1966, through the necessary stages of techhnology and validation, to the introduction of advanced aircraft structures. At present, designs in carbon fibre composite materials are limited to about 30% of the material's full capability (see Figure 4). because of reductions in compression strength due to impact damage[1] and to the hot/wet performance of the resin matrix.[2] Even so, using these design limits, composite components can be made which save both weight and manufacturing cost compared with metal equivalents. Improved understanding of the material's behaviour and improved structural design will allow more efficient use, and new composite materials are being developed with significantly better performance. Major structural demonstrator items in the UK include the Tornado taileron, the Jaguar engine bay doors, the Jaguar wing and advanced fuselage parts for helicopters. A small number of items, such as Rolls Royce RB 211 engine cowling doors and Westland Helicopters rotor blades, are actually in production

ADVANCED COMPOSITE MATERIALS

FIBRE	MATRIX	
CARBON		EPOXY
GLASS	THERMOSET	POLYESTER
ARAMID		POLYIMIDE
BORON	THERMOPLASTIC	
POLYMER	METAL	
CERAMIC	CERAMIC	

Figure 1

Fibres and matrices used in advanced composite materials

ADVANCED COMPOSITE STRUCTURES

MOULD COMPLEX SHAPES → COST SAVING IN MANUFACTURE

DAMAGE TOLERANCE
REPAIRABILITY → LOW INSPECTION AND MAINTENANCE COSTS

AERDELASTIC TAILORING → IMPROVED EFFICIENCY
NEW CONCEPTS
(FORWARD SWEPT WING)

Figure 2

Advantages derived from the use of advanced composite structures

CARBON FIBRE COMPOSITE MATERIALS

HIGH STRENGTH
HIGH STIFFNESS → WEIGHT SAVING
LOW DENSITY → IMPROVED PERFORMANCE

FATIGUE RESISTANCE → GOOD DYNAMIC PERFORMANCE
CORROSION RESISTANCE → (HELICOPTER ROTOR BLADES)

Figure 3

Specific advantages of carbon fibre composite materials

COMPOSITE DEVELOPMENT

1966 RAE CARBON FIBRE PROCESS
1968 INITIAL EVALUATIONS
1970 DEVELOPMENT ITEMS IN SERVICE
1973 MATERIALS DEVELOPMENT
1975 DESIGN DATA
1976 MANUFACTURING DEMONSTRATORS
1979 AIRWORTHINESS DATA
1981 REPAIR TECHNOLOGY
↘ ADVANCED COMBAT AIRCRAFT

Figure 4

Summary of carbon fibre composite development

and the number of applications will increase substantially in the immediate future. It will be essential for maintenance engineers and accident investigators to become familiar with the behaviour of aircraft structures made from these advanced composite materials.

Fracture of Unidirectional Composites

Composite materials derive their high specific strength and stiffness mainly from the fibres. The fibre stress-strain curve is important in determining the strength and modulus of the composite material, and also the area under the stress-strain curve represents the energy needed to fail the fibres. The matrix is required to transfer loads between the fibres by shear, to provide adequate strength perpendicular to the fibres and to support the fibres against buckling under compressive loading. Of crucial significance to the performance of composites is the bond between the fibre and the matrix. It is the ability of composite materials to deflect cracks along the fibre/matrix interface that gives them their toughness and characteristic fracture behaviour. Carbon fibres have to have an oxidative surface treatment in order to achieve an adequate bond between the fibres and a resin matrix. This is illustrated in Figure 6. The shear strength τ of unidirectional composites

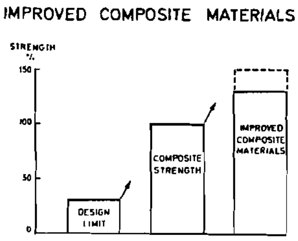


Figure 5

Potential for improvement in the use of composite materials

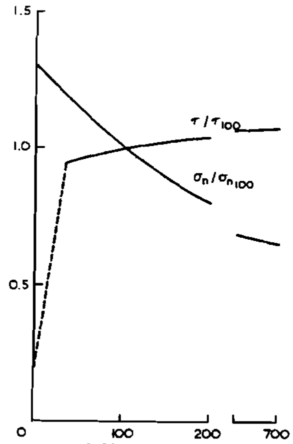


Figure 6

The effect of fibre surface treatment or fibre/matrix bond strength on the interlaminar shear strength τ and the notched tensile strength σn of carbon fibre composite laminates

increases with the level of surface treatment, enabling more load to be carried in shear or transverse to the fibres. But the strength of notched multidirectional laminates on decreases with increasing level of surface treatment, indicating that the laminate is becoming more brittle. The surface treatment has to be optimized to give adequate performance in tension, compression and shear.

The strength of notched specimens is an important measure of a material's engineering value. Figure 7 shows that with anisotropic composite materials, local shear stresses at the notch tip or local transverse tensile stresses ahead of the notch tip can cause cracks to grow along the relatively weak interface between the fibres, parallel to the applied tensile load. This effectively blunts the notch, reducing the stress concentration at the notch tip, and can make the material insensitive to notches. It is this tendency to fracture parallel to the fibres in response to small local stresses, rather than across fibres in response to the larger applied stress, that characterizes the behaviour of composite materials and gives them their toughness.

Multidirectional Laminates

For many practical applications, the composite material has to have strength and stiffness in more than one direction. Multidirectional laminates are made by stacking thin plies (typically 0.125 mm) oriented at different angles (usually 0°, 90°, + 45° and – 45°) according to the stressing of the component. The stacking sequence for most applications has to be "symmetrical" about the mid-plane and "balanced" in + 45° and – 45° plies to avoid distortions of the laminate.

There is a well-developed laminate plate theory[3] to calculate the elastic properties of these laminated. For calculations of strength there has to be a failure criterion, and several of these exist for simply loaded specimens. The behaviour of notched laminates is more difficult to predict. Cracks run from the notch tip in different directions, parallel to the fibres in each ply, and delaiminations occur between the plies. Thus a damage zone develops at the notch tip which both blunts the notch and absorbs energy.[4] The extent of this damage zone and hence the toughness of the laminate depends on the fibre, matrix and interface properties, on the ply thicknesses and stacking sequence and on the loading. These crack-blunting mechanisms are illustrated for compressive loading in Figure 8. Under room temperature, dry conditions many of these cracks can form parallel to the fibres, reducing the stress concentrating effects of the notch and giving a good notched

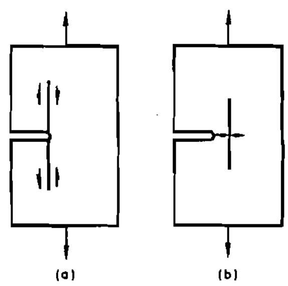


Figure 7

Crack blunting mechanisms in unidirectional composites

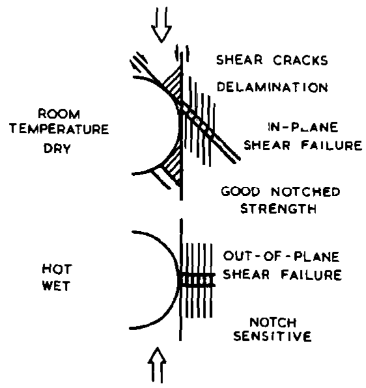


Figure 8

Failure modes in notched compression tests on carbon fibre composite laminates

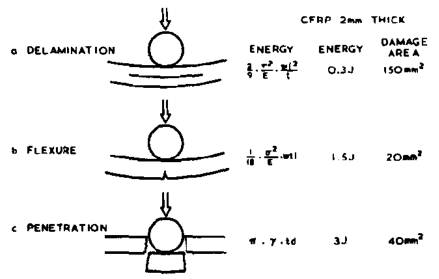


Figure 9

Failure modes under impact loading of carbon fibre composite laminates

strength. However if the matrix absorbs moisture and the composite is tested at elevated temperature, the matrix can no longer support the fibres adequately and they can buckle out-of-plane in response to the concentrated stress at the notch tip, at relatively low applied loads.[6] Thus in trying to predict the behaviour of composite materials it is important to know the effect of material and test parameters on all the possible failure modes, so that the appropriate failure criteria may be used.

Other properties of multidirectional laminates which cannot at present be adequately predicted from unidirectional ply properties are impact performance, bearing strengths at fasteners and fatigue properties. Further complications are introduced by the use of carbon fibre fabrics of various types for the reinforcement; these have certain advantages in manufacture and in certain failure processes.[6]

Impact

Impact by some foreign bodies such as a dropped tool, a runway stone, a bird, a hailstone or other projectile tends to cause complex loading which may be more localized at higher velocities because loads have to be reacted in a time short compared with the time for stress waves to reach support structure. Differences in material properties, in structural response and in the details of the impact event can result in different

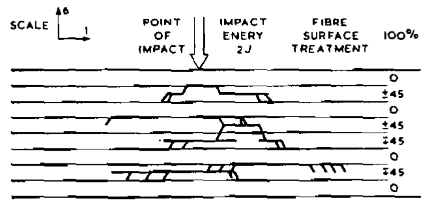


Figure 10

Multiple delamination caused by drop weight impact on a carbon fibre composite laminate

types of failure, some of which will be more detrimental to structural performance than others.[7] Figure 9 illustrates the main forms of damage, the threshold energy needed to cause them in typical 2 mm thick CFRP laminates and the area of fracture surface that would result if all that energy were converted into damage. The symbols, w, t and l refer to the width, the thickness and the span of the laminate, E is the Young's modulus, τ the interlaminar shear strength, σ the flexural strength, γ the through thickness fracture energy and d the diameter of the hole. Delamination affects interlaminar shear strength and compression strength but has little effect on tensile strength. Broken fibres in flexural failures or penetration tend to reduce tensile strength more than compression strength. Typical damage in delamination is shown in more detail in Figure 10. There can be significant internal damage with no sign on the impacted surface. At greater incident energies, damage becomes visible on the back face but there may still be nothing visible on the impacted face. Eventually, at higher energies, damage becomes plainly visible on both surfaces. The phenomenon of barely visible impact damage is known as BVID.

The effects of impact damage on structural performance are illustrated by the example in Figure 11. From 0.5J to 3J of drop weight impact energy causes internal delamination. This has little effect on tensile strength but reduces the compression strength by up to 50%. Greater impact energies cause fibre fracture and this causes a reduction in tensile strength. The 3J impact resulted in BVID and this was used as a stan-

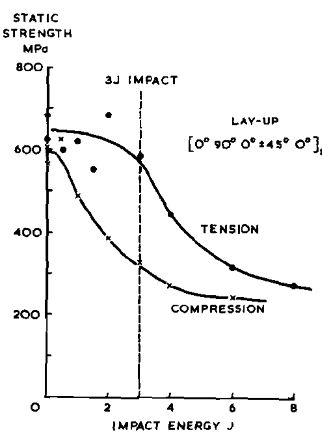


Figure 11

Effects of drop weight impact damage on the tensils and compressive strengths of a carbon fibre composite laminate

dard level of damage to investigate possible damage growth under fatigue loading. The results are shown in Figure 12 for fully reversed cyclic loading, with equal loads in tension and compression. The undamaged laminate showed a typically sloping S-N fatigue curve. The 3J damaged laminate had a 50% reduction in short life fatigue strength because of the reduction in static compression strength, but subsequent fatigue loading caused very little degradation in strength. The S-N curve was very flat and at 10^6 cycles there was little difference between the fatigue strengths of the damaged and undamaged laminates. Evidently the crack blunting mechanisms described above reduce the stress concentrations caused by impact damage and this is a fairly general result for different carbon fibre laminates and different forms of impact damage (see reference 8). If design limits allow for the effects of BVID then it seems that fatigue is not a general problem. There is more concern with the probability of accidental damage causing reductions in static strength.

These observations and conclusions, above, apply to failure modes in first generation carbon fibre/epoxy laminates. Great care must be taken when new materials are used, such as toughened epoxies and thermoplastics, because different failure modes are known to occur.[9] For example, carbon fibre/PEEK (polyetheretherketone - a semi-crystalline thermoplastic of current interest for advanced composite structures), when subjected to drop weight shows surface indentations which may have associated compression damage caused by fibre microbuckling.[10] Because PEEK is tougher than current epoxy resins there is less delamination damage during impact and less delamination growth during subsequent compression loading. Thus carbon fibre/PEEK laminates show less degradation in compressive strength as shown in Figure 13. In addition, the damage is more visible at lower energies, so that the BVID design allowables are greater than 80% of the ultimate compression strength compared with only 50% for many carbon fibre/epoxy laminates.

There are also significant improvements in carbon fibre strengths which should further improve the impact performance of carbon fibre laminates. However, other requirements such as that for higher temperature performance for military aircraft or for applications near engines, may result in the use of polyimides or bismaleimides, and these could well be relatively brittle. The question of impact sensitivity of composite materials will need to be carefully monitored for a considerable time.

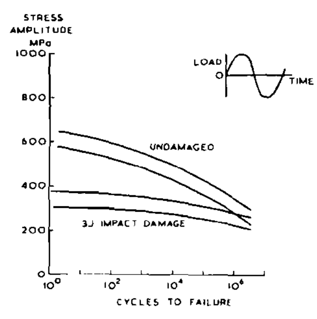


Figure 12

Post impact fatigue under fully reversed cyclic loading of damaged and undamaged carbon fibre composite laminate specimens

Composite Structures

Further complications are introduced by the many different structural forms and their various structural elements such as curved panels, honeycomb panels, angle sections, tapered sections, cut-outs, fasteners, bondlines and joints. These can result in local stress concentrations with complex stresses, buckling and post-buckling behaviour and out-of-plane loading and interlaminar stresses, all of which might be affected by local damage. Stiffer parts of a structure may transfer loads and cause damage elsewhere in a component. Figure 14 shows a result of impacting a stiffened panel, resulting in damage well away from the point of impact.

Composite materials can be a significant specific energy absorbing capacity and they are being considered for making aircraft structures more crashworthy[7] either by adding energy absorbing composite material or by incorporating it into the load bearing structure.[11] Particular problems arise from combining metal and composite components in a structure. Because composite parts have a slightly higher variability than metal parts the metal part will in general be stressed to a higher proportion of its strength. Thus, in testing or in service, one would be more likely to see a failure of the metal part. This is particularly so in fatigue and many test houses have observed fatigue failures in metal end fittings when ostensibly testing a composite specimen.

It is not possible to cover the behaviour of the wide range of composite structures, but significant bodies of knowledge are being established and are giving confidence in the use of composites in aircraft structures.

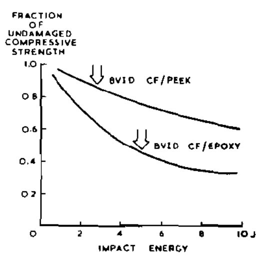


Figure 13

The effect of barely visible impact damage on the compression strengths of carbon fibre/epoxy and carbon fibre/PEEK laminates

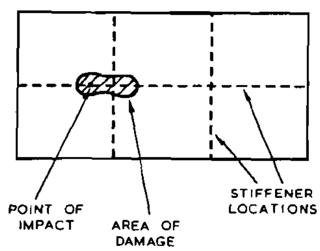


Figure 14

Interactions between impact loading and structural response in causing damage

Fractography and Failure Analysis

An important part of the analysis of failures in metal parts has been the use of microscopic examination of fracture surfaces. This may establish the point of initial failure and the mechanism of crack growth such as fatigue or stress corrosion. It is important that this kind of expertise is established for composite materials. Composite specimens that have failed under known loading by a known failure mode are being examined by optical and scanning electron microscope so that their fracture surfaces can be characterized both for type of failure and for direction of crack propagation.[12] Much of this has already been done for static failures in first generation carbon fibre/epoxy laminates. This knowledge has then been applied to the failure analysis of large structural parts failed in static ground tests. In many cases the point of failure and cause of failure have been established, and failure loads have been explained and related to defects in the structure. The steps in such an analysis are shown in the following sequence:

local failure mode → movement diagram

local composite quality → local sustainable stress

movement diagram + local sustainable stress → failure sequence → primary cause of failure

Similar work will have to be done for fatigue loading, although with present composite materials fatigue is less of a problem than it is with metals.

Conclusion

Research and development work on composite materials and structures, such as that at the Royal Aircraft Establishment, is aimed at generating an understanding of behaviour and at improvements in performance. In characterising the behaviour of composite materials it is important to know the mode of failure in any situation so that models can be developed to predict the strength. Modifications to the material to give improvements in performance, whether improved toughness or increased temperature performance, might cause changes in the mode of failure. This would have important implications for strength prediction and for fractography and failure analysis.

With the increased use of composites in aircraft structures there is a need for feedback from in-service experience, with liaison between research and development (RAE, Universities), manufacturers (BAe, WHL, Shorts), airworthiness authorities (RAE, CAA), users (RAF, BA) and accident investigators (AIB). In this way it will be possible to build up in the aerospace community a significant body of expertise in understanding the behaviour of advanced composite materials and structures.

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Graham Dorey graduated from Trinity College Cambridge with an Honours Degree in Natural Sciences (Physics) and joined RAE where he started work on hardening mechanisms in copper. Carbon fibres, developed at RAE, were then becoming of increasing interest and he studied the problem of impact damage in CFRP. For the past 9 years he has led the Composite Materials Section covering static and fatigue properties, fracture characteristics, effects of impact damage and environment, the development of improved fibres and detailed investigations of interactions between fibres and matrix.

BO-105 in the Gulf of Mexico

Bob Orr - Boeing Vertol
ISASI M00591

Good morning ladies and gentlemen and a special greeting to our hosts here in England at our 14th annual seminar. It gives me a great deal of pleasure to be here. I will be presenting to you work associated with a helicopter accident but, I feel the area to be covered can be applicable to many accident investigations, be it helicopter or fixed wing.

I would like to state that this paper is not intended to be a paper on determining the cause of an accident. The actual cause of the accident is presented in the findings of the National Transportation Safety Board and will not be discussed during the presentation. What I will discuss is the effort that went into the on-site portion of the accident investigation. In other words, what tools were utilized to bring the field portion of the investigation to completion.

You may ask why is a Boeing Vertol Investigator presenting a paper on an MBB 105 helicopter. For many years Boeing and MBB have had a close business relationship. During the time of the accident being discussed today, Boeing Vertol had a distributorship arrangement with MBB. This agreement covered marketing, repair, overhaul, spares and engineering support for BO-105's in the United States and several other countries in the Western Hemisphere. It also included an active role in accident investigation support.

This paper today will deal with a search for helicopter parts following an accident and the "resources" used to assist in the search for these helicopter parts during the on-site portion of an helicopter accident investigation.

Let us start with the sequence of events for this accident. It took place on the 13th of June, 1975. The flight had originated at Intercoastal City, Louisiana. (Fig. 1) Intercoastal City is a town on the Gulf of Mexico in Louisiana located not quite half way between New Orleans, Louisiana and Galveston, Texas. (Fig. 2) The city is located a few miles in from the shoreline of the Gulf but it is adjacent to a large tidal area with a large surrounding marsh. The aircraft number is N149BB, the flight number is U41 standing for Union Oil Company flight number 41. The mission was to deliver three passengers to an oil rig in the Gulf of Mexico. The helicopter lifted off the helo pad at approximately 1625 hours and departed to the southwest, paralleling the road which runs through Intercoastal City. When it arrived at the southwest end of town the helicopter broke to the left and picked up a heading of approximately 160° magnetic. All the time the helicopter was continuing to climb. It was estimated that it had climbed to somewhere between 500 and 1,000 feet ASL when the pilot reported back to Petroleum Helicopters Inc. (PHI), Intercoastal City control for helicopter operations that "I have a problem up front, I'm going in the water, I'm going in the water, do you read me". This was followed very shortly within 20 or 30 seconds by a second radio transmission which said, "I'm going in the water, I'm going in the water, do you read me, do you read me." PHI Intercoastal City helicopter control immediately requested assistance from any other helicopters in the area to report any information on this helicopter.

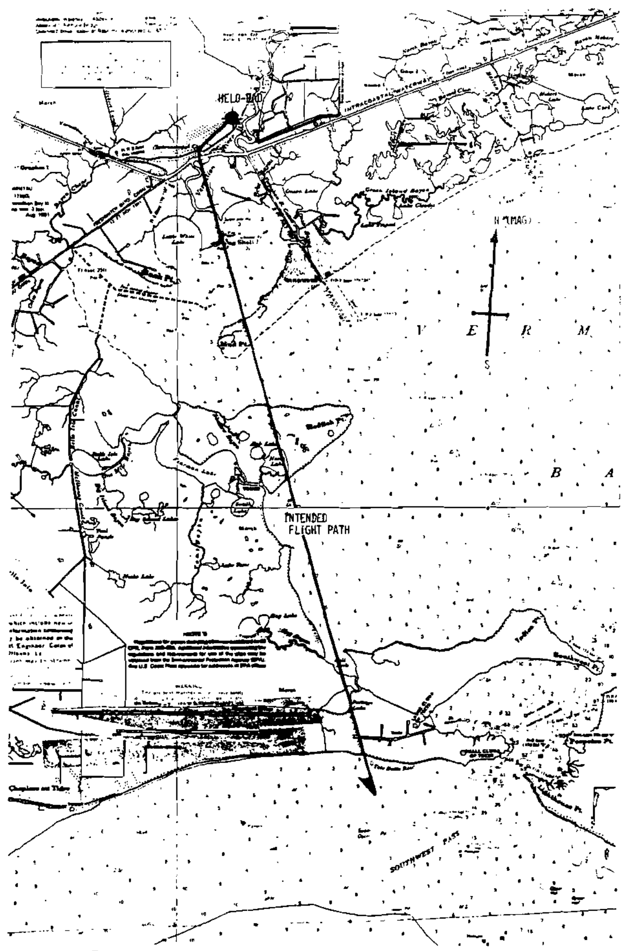


Figure 2

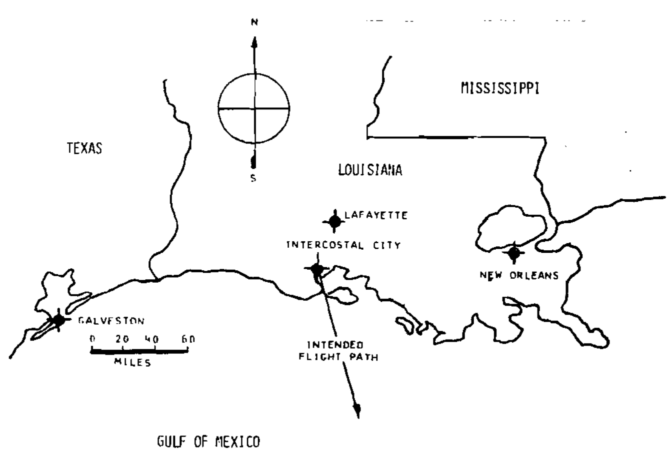


Figure 1

(Fig. 3) The aircraft impacted at a point about three miles from takeoff and was lying on its side in an area of Vermillion Bay, which was rather shallow. The mean low water was about four feet in the impact area. (Fig. 4) This area had a tidal action of about two feet, so the water depth between tides runs from four to six feet. A helicopter in the area which initially spotted the downed aircraft now directed the sheriff's department boat which was responding to the distress call, to the area along with several other small boats. Three passengers and the pilot were removed from the aircraft and taken to the hospital where the passengers were treated and released. The pilot sustained fatal injuries.

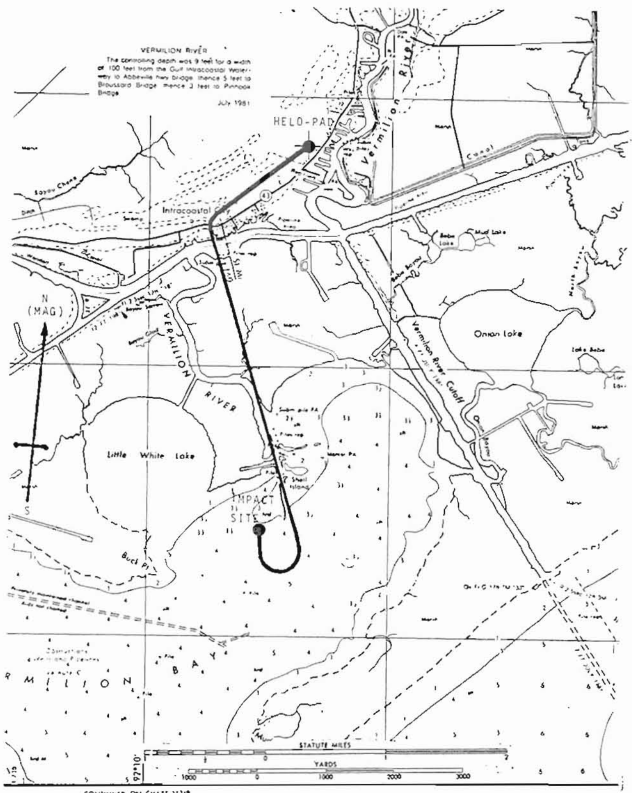


Figure 3

One of the first tools required was a very shallow draft recovery vessel capable of lifting the wreckage. A small work barge, the type used in coastal areas for pile driving and construction of bulkheads, was utilized for this wreckage recovery. It has shallow draft and a small crane on board capable of lifting the wreckage. They were able to lift the wreckage out of the water and then transported it to Intercoastal City. It was then placed on a flat bed truck and taken to Lafayette, Louisiana. This is the main maintenance point for Petroleum Helicopters Inc. in that area. There the aircraft was washed down and steps were taken to try to protect it from the effect of salt water immersion. The small barge that was utilized is an excellent tool in coastal water areas. These barges are designed for working around docks, and bulkheads in relatively shallow waters and yet they have a good lifting capacity because they have to be able to lift large timbers and pilings. This is an item that you can use when you're working in shallow water and need some kind of heavy recovery capability.

(Fig. 5) As you can see here from the picture of the aircraft, probably the most significant item is the fact that the entire tail rotor, tail rotor gearbox, tail rotor control system and the upper portion of the pylon are missing. We could spend a good deal of time on this slide discussing many of the things that were noted, but I would like to continue with the crash site search portion of this investigation. I will tell you that the accident investigation team did spend a good deal of time looking over this wreckage and trying to analyse the break-up sequence.

One of the next items was to develop a wreckage diagram. We were quite fortunate in this case in that there was a very alert pilot on the aircraft which first came to assist at the impact site. As soon as he directed the boats into the crash area, he hovered over the scene and made a sketch of what could be seen in the crash site. I might add, it was an excellent job considering he had to pilot the aircraft and sketch at the same time. (Fig. 6) You will note here from the wreckage diagram there is the main wreckage area with a rather large oil slick and some debris floating around and the other area off to the left side is a second oil slick with some floating debris. One of the items was a piece of tail rotor blade in that secondary slick area. At the time we thought this would give us a very good shot at finding the tail rotor gearbox which by now had become the central theme in our search during this investigation. Several days after the crash, a few more items were

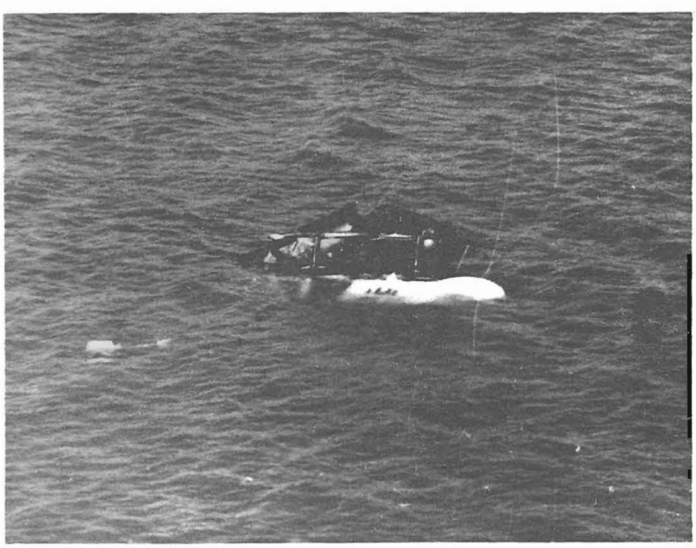


Figure 4

Figure 5

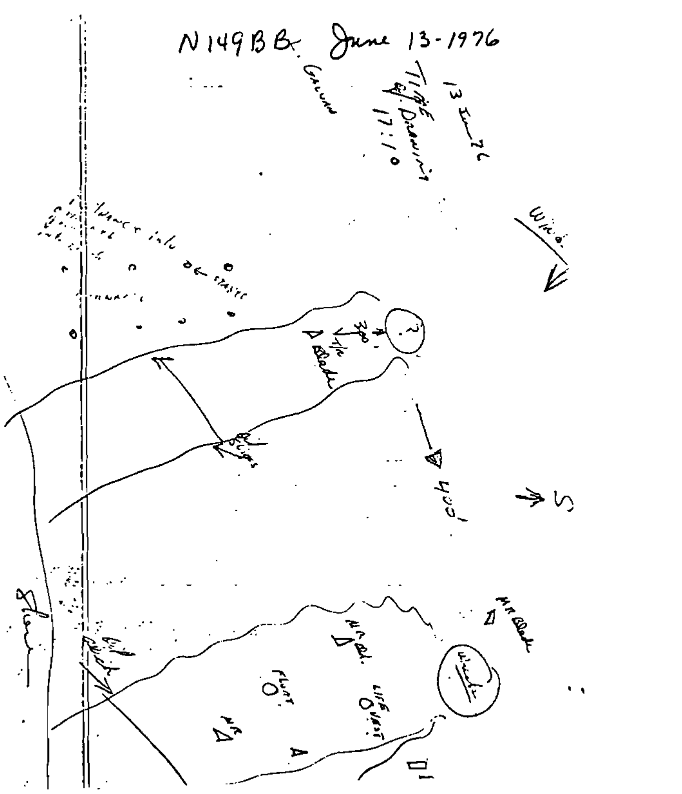


Figure 6

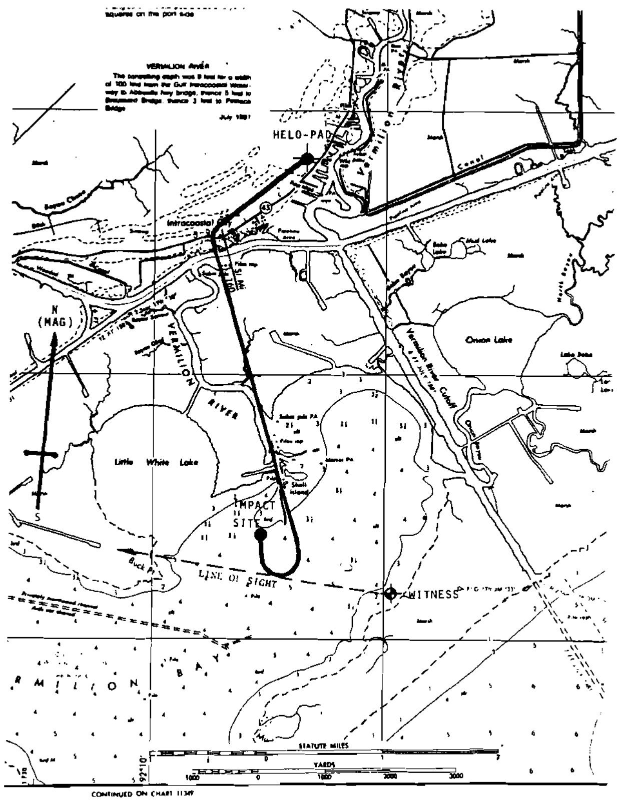


Figure 7

added to the wreckage diagram. Searches were made along the beach or swamp areas and we did pick up a few bits and pieces of debris which had floated ashore following the crash.

The next element in our search of course is witness statements. We started with the passengers. Only a little information was gained here because most of the oil workers that travel in helicopters in the Gulf area are like other working people getting up in the morning and taking a bus downtown to work. They get on the helicopter, then they either go to sleep, read a book or a newspaper or chit chat with their fellow passengers. Helicopter travel has become a very routine thing. The only thing they could really report was, there was a thump, or a bang followed by a shudder, the helicopter began turning and then began spinning. It was very hard to sort out exactly which way the helicopter turned and which way it spun. Later it was determined that the helicopter was turning to the right but ended up spinning to the left while banking and descending. It's difficult for a passenger to fully describe what he went through especially when he was not prepared for the sequence of events which was very short. None of the passengers were able to pinpoint the route flown. (Fig. 7) You will note on the diagram there was one witness on the bay, who was in a boat fishing, about a mile away. He reported seeing the aircraft and he presented us with quite a problem. His initial report said that the airplane turned to the left. Later he said, he thought it turned to the right. He did confirm that the airplane was spinning, but was unable to determine the direction of the spin. The most significant point that could be drawn from his witness statement was that we were able to draw a boundary line which the aircraft never passed beyond. We were then able to establish the farthest movement of the aircraft from Intercoastal City and that became one of our boundaries for a search zone.

While completing the witness interrogation and flight simulation, there was one other thing going on at the same time; that was a scuba search. We had a diver from an ocean engineering firm go down around the area of the main wreckage and do what they call a circle search to see if any additional wreckage or debris could be located at the impact site. There was nothing of any real significance found in this search, i.e., we did not find the mail tail rotor assembly or any of its associated major parts. At this point we had completed what you might call the standard textbook investigation. We had photographed the crash site, photographed the recovered wreckage and engineers had extensively reviewed the wreckage. Our wreckage diagrams were completed, we had our witness statements, and a review was made of the aircraft maintenance records.

We sat down at this point and tried to determine what could be a scenario of this accident. We came up with four areas that we felt might support this kind of tail rotor pylon breakup. (Fig. 8) One would be fatigue failure of a tail rotor blade; a second would be possible loss of a tail rotor blade due to foreign object damage; third would be foreign object damage to the pylon which allowed the tail rotor unit to come free; and the fourth would be some type of sudden stoppage in tail rotor drive system. With such wide spread possible scenarios and with so many unanswered questions, the Boeing Vertol Company, MBB, and Petroleum Helicopters management decided they could not allow this investigation to stop at this point. The resources of the three companies would be expended in an extensive search to locate the tail rotor gearbox assembly and the associated parts. The first step in this new search program was to go back and get the diver from the ocean engineering firm and start a renewed search of the impact site. This search consisted of putting a stake in the center

Figure 8

of the impact area. A lanyard was then attached to this stake. This lanyard had distance markings on it in the form of knots every so many feet out from the center of rotation. The diver starting next to the stake completed a 360 degree sweep around the stake while searching the bottom for any pieces of wreckage. Before we go any farther, I'd like to tell you the conditions under which the diver had to search. This bay is in the Louisiana Bayou Country. The water visibility in the search area was about 18 inches at best for the diver. In other words, he could only see approximately 18 inches in front of him due to the turbidity of the water. In addition, the bottom was a black oozing mud. If a person attempted to stand on the bottom, they would sink up to about their knees. Our fear from the very beginning was that anything that went in there of any weight would immediately sink down into this mud. These fears were later confirmed. As the diver searched, feeling through the mud, he was stirring up more mud so that his visibility was further reduced.

Recognizing that the gear box could have left the helicopter at any point along the flight path after the bang and shudder, a request was forwarded to the Boeing Vertol aero performance people to make a trajectory study in order to lay out a search area based on the flight path of the helicopter. (Figs. 9 and 10) These two charts show the development of the projected trajectory area. These studies more or less were our guide through the balance of the search for the gearbox and associated parts.

One of the next items after this was an inquiry to the United States military on availability and capability of air-

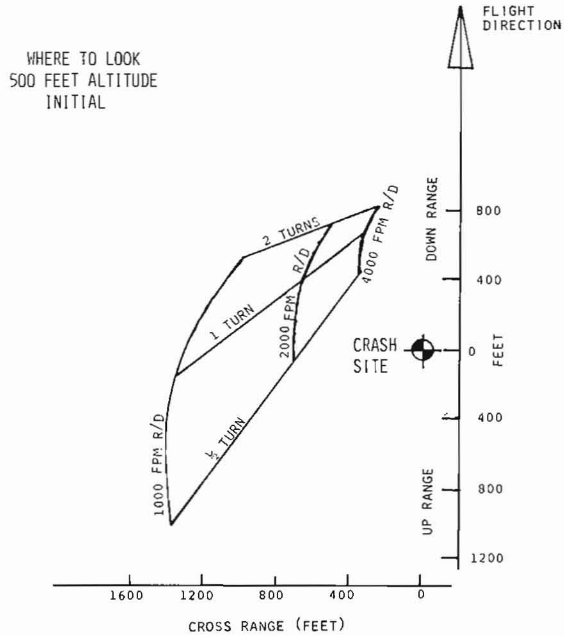


Figure 9

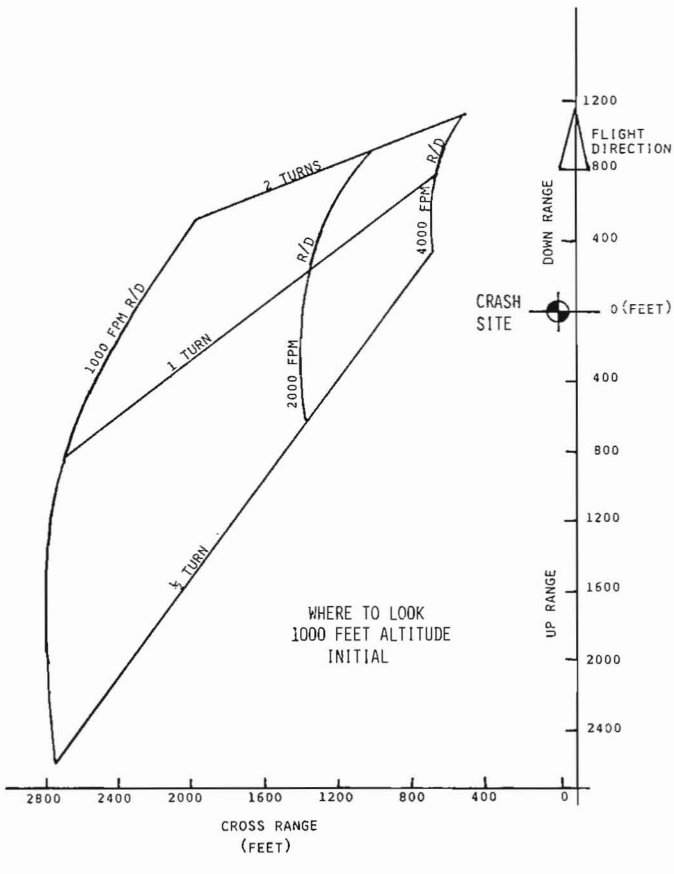


Figure 10

borne and surface vessels. The questions were, what would be the availability of their vehicles and what would be the probability of pinpointing the gearbox location. Discussions with the military revealed that from an airborne standpoint, they could not identify an area much smaller that the area we were searching. Discussions on surface vessels revealed that the Navy equipment was just not suited for operation in the shallow waters surrounding the impact area.

Utilizing the trajectory study, an expanded search program was initiated. (Fig. 11) A square was laid out which encompassed the two trajectory areas and then was broken up into four quadrants which were defined as the areas of search. Each one of these quadrants was assigned a number which was considered in a priority order of 1, 2, 3, and 4. The first search attempts were made by using small bay boats dragging shrimp trawls. (Fig. 12) These shrimp trawls are an excellent tool for searching for small to medium size items, the reason being you cover a fairly large area in a short period of time. The shrimp trawl, by design puts the net down on the bottom of the bay. There are two doors on either side of the net called trawl doors. These doors keep the net spread and down. Between them there is a steel cable which is running on the bottom of the bay floor or actually maybe an inch or so below the bay bottom because of its weight and trawl door angle. In the shrimp operation the shrimp lay on the bottom and when the steel cable comes along and tickles them on the bottom, they jump and then the net gets them. We used two boats initially and swept with the two boats for almost a week crisscrossing the area. Very little was brought up other than shrimp. Several pieces of torn airframe skin and fairing material were recovered. Again the problem was one of the heavy black mud. It was felt that the parts we were looking for most likely had settled down into the mud and were below the level of the steel cable on the shrimp net.

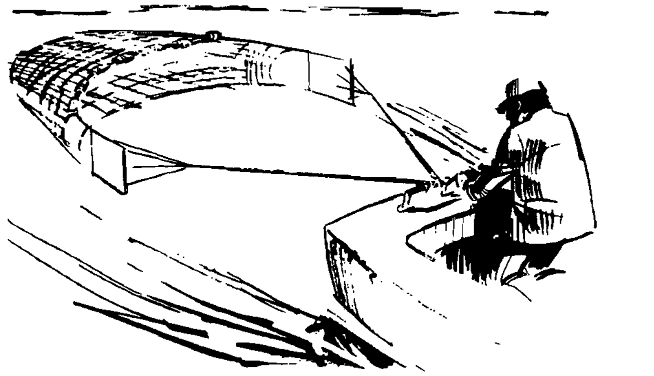


Figure 12

During this time period in the search, we continued to explore ideas on how to speed up the search and how to refine the search in terms of reducing the size of the search area. One of the items that was undertaken was to try to determine the original impact site on the water of the tail rotor blade which was noted in the secondary slick in the wreckage diagram. It was felt that this tail rotor piece was light, would have had little or no trajectory, and if we could pinpoint where it initially entered the water, we would be able to close down the size of the search area. Studies were made of the tide tables and the weather from the day of the crash, then a day with a window closely approximating the conditions of weather and tide at the time of impact was selected. A wooden model of the broken tail rotor blade was fabricated and set adrift. It was allowed to drift for the elapsed time between the crash and the time on the wreckage diagram prepared by the helicopter pilot. A plot was made of the distance drifted and the direction of drift. (Fig. 13) Placing this back on the search/ wreckage diagram, it was noted that the blade came close to being in the trajectory

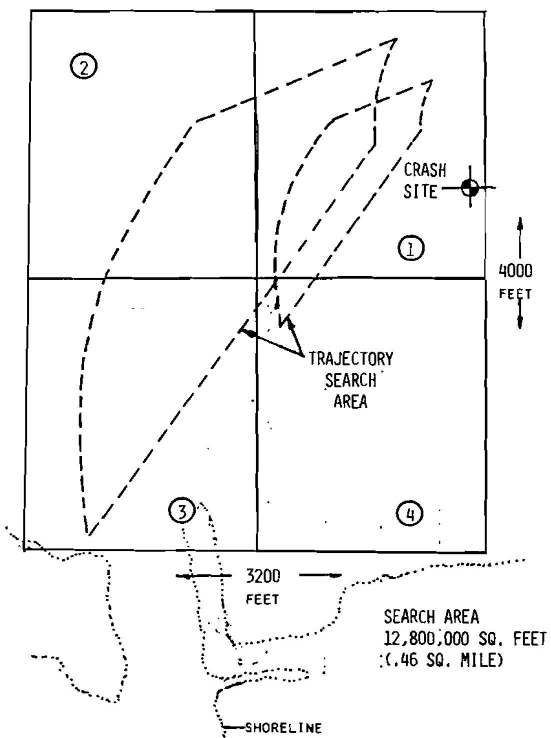


Figure 11

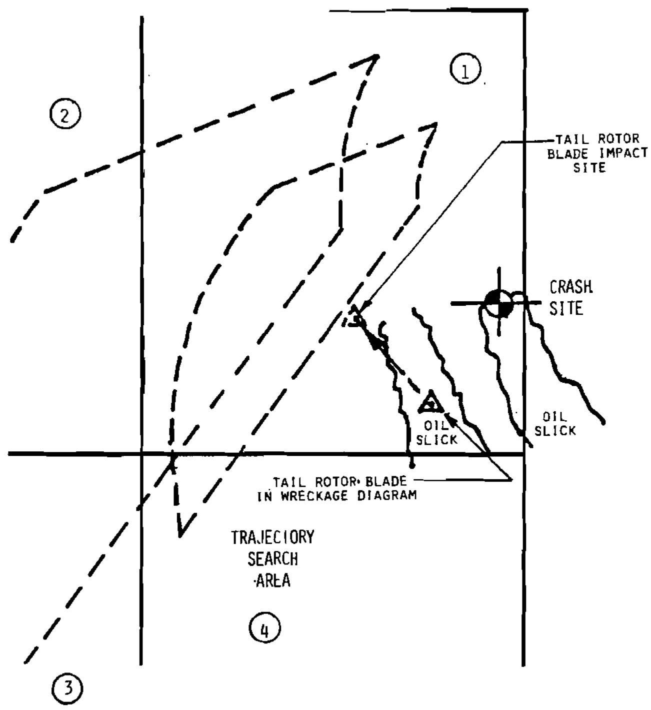


Figure 13

search area for a 180° turn @ 2000 FPM rate of descent from 500 feet ASL. Things you have to watch when you do this are not only do you have to come up with approximately the same weather conditions such as the wind, you have to have the same tide time and you must find a tide with approximately the same rise and fall as the day of the accident. The tides rise and fall will vary from day to day and will affect currents. We were fortunate in the Gulf area that at this time of the year, in the afternoon the weather usually shifts to a breeze from off the Gulf very much at the same velocity and heading every day so we didn't have to worry too much about the weather window. What was required was finding a good tide table window.

Another area that was looked at was hand held underwater sonar. One was obtained and used for a short period of time. The desired results were not forthcoming with the underwater sonar unit. Two things contributed to the termination of the search by portable underwater sonar. (Fig. 14) One, the unit would become completely imbedded in the mud, because of its weight due to the shape of the bay bottom. Over the years the scouring or scrapping of the bay bottom by shrimp netters had created a wash board or rippled contour. These ridges acted as baffles and impeded the sonar signal to the extent of creating false echoes and a very limited range.

Another item that was considered was military mine detectors. The diver in his search at the bottom, because of the visibility problem, literally had to search the bottom with his hands and this created even a greater problem as far as visibility was concerned. (Fig. 15) What was finally utilized was a small hobbycraft metal detector. We went to a hobby shop and looked at a number of these small metal detectors that people use for looking for coins on the beach and searching for artifacts around old diggings. This proved to be a very successful addition to our list of search tools. They are extremely light, have very small power supplies and many of them will stand a certain amount of water immersion. A number of these units were obtained and were encapsulated in plastic bags, so that they operated fairly well underwater for reasonable periods of time. It is not known if this would be the case if the water depth was significantly deeper than where our operation was taking place, but in this case it turned out to be very successful and assisted the diver as far as reducing his search time in each of his circle searches. Further explanations when we get into our final search will reveal why this turned out to be such a successful choice of equipment.

After several days of intensive searching and sweeping the bay with two shrimp boats and the diver doing an ever expanding circle search around the main wreckage site and secondary slick area it became quite clear that the tail rotor gearbox had to be down in the mud and that a new approach for locating it must be considered. Discussions with the oil service companies on techniques to locate buried pipe lines brought us to our final search tool, a magnatometer. It is used for locating underground pipelines, not only underground on dry land, they also use them to locate pipelines under the ocean floor. A magnatometer and operator were contracted to support us. A model was built, it could be considered a simulated model of the tail rotor gearbox to the extent that it duplicated the ferrous mass of the gearbox and other missing parts. This was tested underwater to determine what the effective range of the magnatometer would be. In the preliminary tests it looked like something in the order of 8 to 10 feet was the effective range. This later on proved to be shorter than the range achieved when the unit was placed in search operation. The actual range was up to 12 to 13 feet there in the bay. The next step was to rig up a search vessel (Fig. 16). The vessel used was about a 25 foot open skiff with an outboard motor. There was a boat operator, a magnatometer operator with the instrumentation and a large number of storage batteries. The magnatometer for this operation was powered by the storage batteries, and this proved to be a real logistics nightmare. It required constant changing and charging of batteries. There

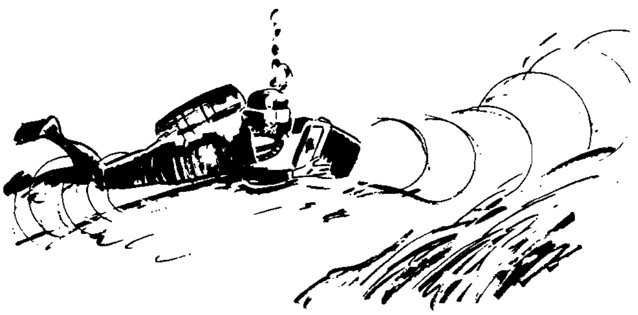


Figure 14

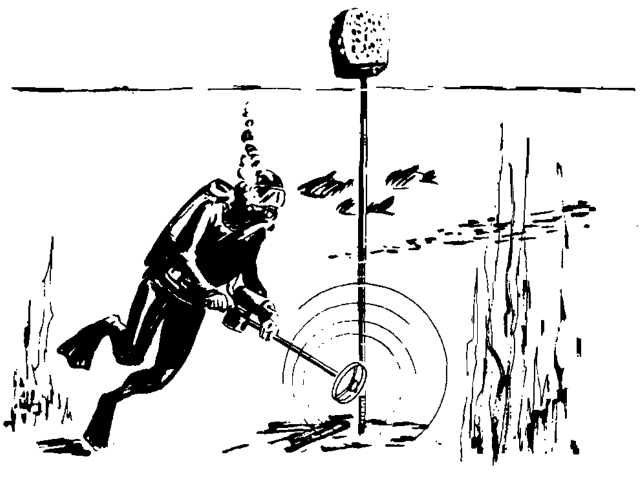


Figure 15

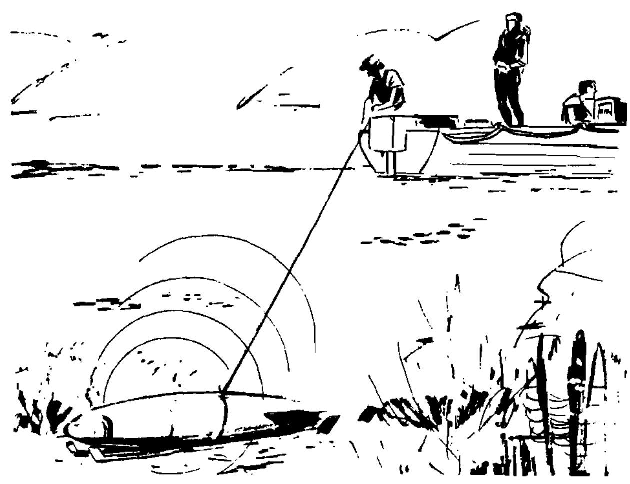


Figure 16

also was what we called a line man or a pole man, in the back of the boat. A second larger vessel was utilized as the dive and navigation boat.

Starting with the original four block search grid, the navigation boat established small rectangles within the search area. The corners were marked with bamboo cane poles. (Fig. 17) Then the magnatometer boat which had a large number of bamboo cane poles on board would start at one of the corners and set up a picket line at the top and the bottom of the rectangle and then the magnatometer boat would weave through the pickets moving at a very slow rate, usually only a couple of knots. When the magnatometer operator would get a signal he would notify the line/pole man and the line man would immediately release the drag line to full slack. The boat operator at the same time would stop and begin to back the vessel down. He would slowly back down until the drag line was directly above the magnatometer. Then the line man would take a bamboo cane pole and feel down till he could find the magnatometer. Then he would insert the bamboo pole into the mud bottom and place a piece of red styrofoam on the top of the bamboo pole. Then the operation would start up again and they would continue the search. It is very slow and is very difficult at times especially when the wind would pick up in the afternoon. It was very difficult for the boat operator to maintain a straight line in the wind while the boat is operating at a very low speed.

The bamboo pole with the styrofoam on it would be an indicator to the diveboat to bring the diver to that location. The diver would then go down with his metal detector and lanyard and begin a circle search around the target area. At the completion of the search the diver would come back up, the red styrofoam target would be removed from the bamboo pole and a piece of white styrofoam would be placed on it indicating it was cleared and the diveboat would proceed to the next target. You would be amazed at the amount of material that's in the Louisiana bayous. To give you an example, the shrimp fishermen use 30 gallon galvanized trash cans for storage of their catches. These cans corrode rather rapidly and the shrimpmen's method of disposal is to drop them over the side. The shrimpmen knew the cans would settle deep in the mud. I believe at the end of the search period there were something in excess of 50 galvanized cans that were removed from the bottom of the bay in our search area. This is the reason why circle searches with hands would be rather fruitless for the diver and the metal detectors at this point proved to be a real bonanza for this operation. This operation was not without frustration. This is something that did not produce results overnight. Twenty-nine days after the crash we located the gearbox and this was only after having completed the search of the entire grid system. It was found by starting to search the grid over again. This time we changed our boats search heading 90°, that is we were crossing our original search lines at 90°. At last success. (Fig. 18) The gearbox was found almost in the middle of the number one priority grid. The real answer to success is, you have to persistently pursue the goal and be willing to try many different means to achieve the goal. I have given you very quickly a rundown of the tools that were used for the field portion of this investigation. Let us review all the tools used:

(a) Rescue Boats
(b) Pile driver work barge
(c) Wreckage diagram (helicopter pilot)
(d) Witness statements (Airborne and Surface Witnesses) including radio transmission
(e) Simulated flights
(f) Wreckage review
(g) Scuba diver
(h) Trajectory study
(i) Tide and current tables for drift simulation
(j) Underwater portable sonar
(k) Shrimp nets
(l) Magnatometer
(m) Hand held metal detectors

Some of the above tools I am sure many investigators have used before. This paper is intended to show a sample of the number of tools available and even though some did not contribute in this particular search they can be utilized under different circumstances and most likely be very valuable tools. You have to look for these tools and, you have to be innovative.

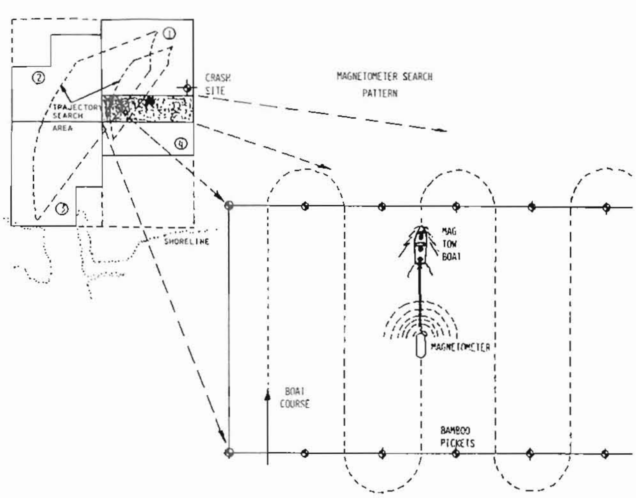


Figure 17

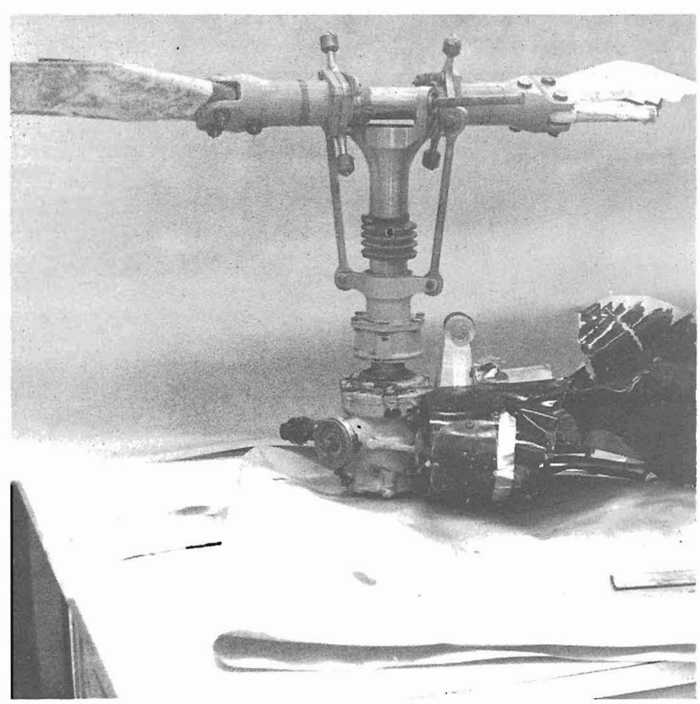


Figure 18

One last comment. Above all you have to look to the local people. They are your best tools because the local people know their area. They live with that environment. These are the people that can give you some of the best assistance available. In this investigation they, the local people, played a very significant role in the successful search I have described.

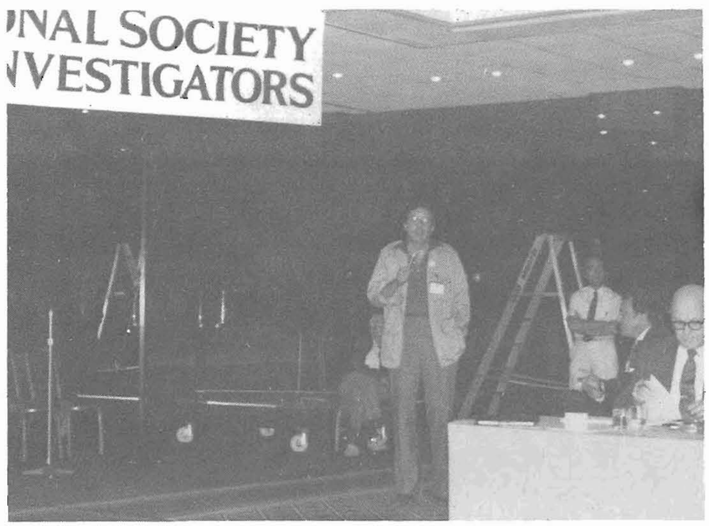
The Author

Bob Orr

Bob Orr served in the US Navy during World War 2 and has since been with the Boeing Vertol Company for 26 years, initially as an airframe design engineer followed by various management appointments. He was appointed as Manager Accident Investigation in 1969. Bob has investigated a large number of helicopter accidents in many parts of the world. Bob is a graduate of the Spring Gordon Institute of Mechanical Design and the USC Accident Investigation Course.

Bob Orr, Boeing Vertol

Bob Rudick



Ira Rimson

A Case History
Bell 212 G-BDIL North Sea

David King,
Principal Inspector of Accidents (Engineering)

G-BDIL was one of a unit of four Bell 212 helicopters normally based on the Treasure Finder semi-submersible accommodation rig in the Brent Field. The aircraft were used in support of the offshore installations for inter-rig transport of personnel and freight and were also capable of providing emergency rescue coverage for the area. The normal offshore pilot complement of the unit was 14 of which four were qualified as night Search and Rescue (SAR) captains. A similar number of pilots were on shore.

The Treasure Finder had been away for approximately 2 weeks in dry dock in Norway and during the period the helicopter unit had had to remove the majority of its equipment to enable it to continue to function while operating 2 of the aircraft from Unst, one from the Uncle John, a semi-submersible diving support vessel and one from the Treasure Hunter, a semi-submersible accommodation rig. At the time of the accident, the Treasure Finder was returning to the Brent Field and the helicopter unit was in the process of re-establishing itself on board. By the evening of 13 September the Treasure Finder was close to the Brent Delta platform with 3 of the helicopters on board and a number of the pilots. Of these pilots two were night qualified SAR captains; one had flown extensively during the day and the other, who was the Chief Pilot in the Brent Field, was the commander of the accident aircraft.

At approximately 0200 hrs on 14 September the unit was alerted to take a doctor and medical attendant to the assistance of an injured man on board the Baffin Seal, a seismic survey vessel operating in the area 5 to 10 miles north of the Murchison platform. Because the helideck of the vessel was obstructed it was decided to fit a winch to the aircraft and to carry a full SAR crew of commander, co-pilot, winch operator and winchman in order to transfer the two medical personnel to the deck of the vessel and if necessary lift off the injured man. The unit operations officer obtained the latest weather report, which indicated the conditions were suitable for such a flight. He was also informed that the Baffin Seal did not carry aeronautical Very High Frequency (VHF) radio or a non-directional beacon (NBD). He was given the position of the vessel in latitude and longitude which he plotted on a Decca chart together with a track, bearing and distance from the Thistle platform. This chart was given to the co-pilot.

The aircraft took off at 0225 hrs and was given clearance to fly at 500 feet on an altimeter pressure setting (QNH) of 1012 millibars. Almost immediately after take-off the aircraft was given the actual and forecast weather for Bergen. The aircraft was then asked by Brent Approach to call the Baffin Seal on marine VHF channel 6. The co-pilot replied at 0231:45 hrs that he had been calling this vessel and he asked Brent Approach to contact the Murchison platform to switch on their NDB and to clear the helideck. A witness on the Murchison saw a Bell 212 approaching the platform from the south at about this time and pass by on the western side at a very low altitude. Two other witnesses on the Murchison stand-by vessel, Grampian Hunter, which was situated 300 yards to the north of the platform, saw the aircraft disappear rapidly from sight in driving rain and poor visibility in a north easterly direction.

Just after 0236 hrs Brent Approach told the aircraft that the Baffin Seal had a searchlight and asked if it would help them if this was pointed vertically. The co-pilot replied at 0237 hrs 'ROGER HE IS FULLY ILLUMINATED AND HE'S LOOKING FOR US WE'RE TALKING TO THEM'. A new QNH of 1011 was passed by Brent Approach at 0239:40 hrs and the immediate acknowledgement of this by the co-pilot was the last tape recorded transmission from the aircraft. Brent Approach called the aircraft next at 0241:20 hrs and after receiving no reply continued to attempt to make contact at frequent intervals. The Brent Logistics Operations controller, who is co-located with the Brent Approach controller on the Cormorant platform, was keeping a diary of the SAR call out and noted that the last call on marine VHF channel 6 at 0242 hrs from the aircraft was 'FIVE MILES NORTH OF THE MURCHISON PLATFORM LETTING DOWN TO SURFACE CONTACT'.

After the repeated attempts by Brent Approach to contact the aircraft without success and similar lack of success by other agencies on other frequencies a state of alert was declared at 0250 hrs. A search by sea and air was put into operation and co-ordinated by the Aberdeen Coastguard and by the Rescue Co-ordination Centre (RCC) at RAF Pitreavie.

A Bell 212 searching in the area 8 to 10 miles north of the Murchison reported at about 0355 hrs that he was in and out of cloud while searching at a height of less than 200 feet. Similar reports of low cloud and poor visibility with driving rain at the time of the accident were received from surface vessels in the area.

Two inflated liferafts floated inverted were found 16 miles north east of the Murchison at 1023 hrs and other pieces of helicopter wreckage and three bodies were sighted during the day in an area 17 to 22 miles north east of the Murchison. The floating debris and two of the bodies were recovered and the search continued until the end of the following day. With the aid of the Underwater Acoustic Beacon fitted to the aircraft the bulk of the wreckage with two more bodies was located on 17 September in a position 030°(T) 14 miles from the Murchison at a depth of 1,120 feet. The wreckage was recovered by vessels under contract to Shell Exploration and Production on 10 October after delays due to extreme weather conditions.

The initial air and sea search for the helicopter resulted in the recovery of various items of floating debris with the bodies of two of the crew members. The body of a third crewman was seen from a surface vessel but adverse weather precluded its recovery. As it appeared that the majority of the helicopter had sunk a salvage vessel was chartered by AIB to attempt to find and recover it.

At 2200 hrs on the day of the accident a suitable ship, the 'Kommandor Michael' equipped with accurate surface navigation equipment, sidescan sonar, two remote control submersibles with underwater video equipment and adequate lifting gear was joined at Peterhead by an Inspector of Accidents in company with marine salvage advisers. In addition to the ship based equipment a Dukane underwater location beacon receiver belonging to AIB was available; the helicopter being equipped with a Dukane acoustic transmitter. A further ship on charter to Shell, the 'British Voyager' equipped similarly to the 'Kommandor Michael' except that it carried manned submersibles, was made available to assist with the search.

The information on the times and locations at which floating debris was recovered from ships involved in the initial surface search enabled a drift plot to be constructed indicating the likely impact positions. This resulted in a location approximately 14 nm on a bearing of 030 °(T) from the Murchison platform. It was agreed that the 'Kommandor Michael' would approach this location from the Murchison 'listening out' with the Dukane receiver covering an area 2 nm either side of the direct track whilst the 'British Voyager' searched with side-scan sonar in the area of the helicopter's last position report, 5 nm north of the Murchison.

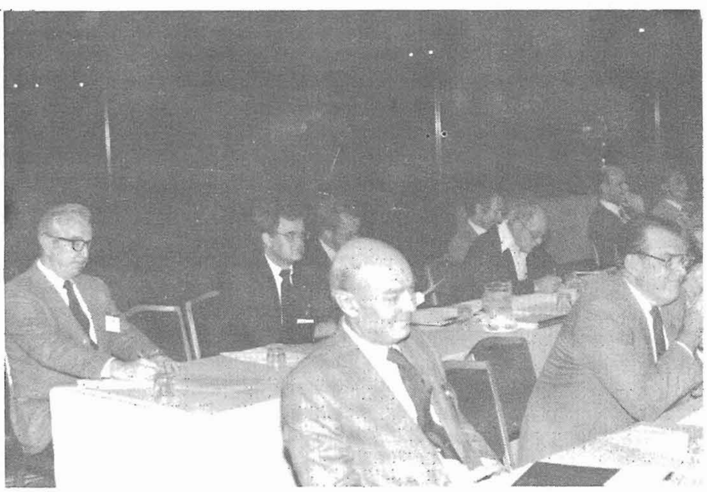
The underwater transmitter on the helicopter was first heard close to the predicted location for the wreckage in the early hours of the 17 September, emitting two pulses per second and not one as specified. Having refined the location using the Dukane equipment a manned submersible from the 'British Voyager' confirmed that the signal was an emission from G-BDIL lying in approximately 1,100 ft of water. The submarine undertook an extensive video survey of the wreckage during which the bodies of two further crewmen were located one inside and the other outside the fuselage.

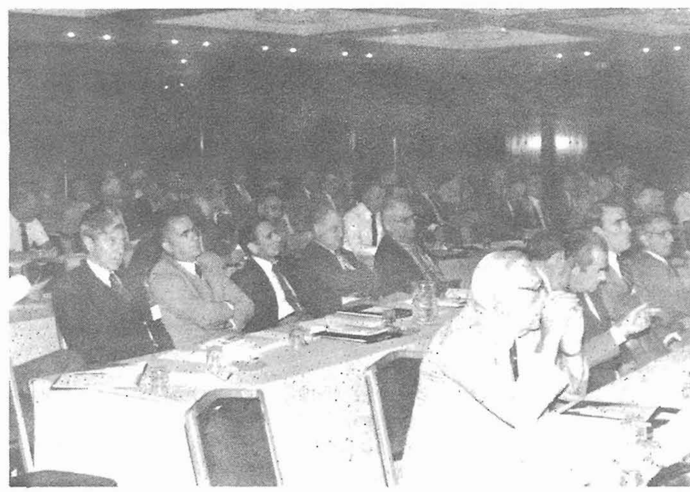
The AIB team transferred to the 'British Voyager' and, with the assistance of the semi-submersible lifting vessel the 'Uncle John' provided by Shell, the wreckage was finally lifted to the surface on 10 October. The delay between location and recovery was due to the difficulties resulting from the depth of the wreckage along with its flimsy nature making attachment for lifting extremely difficullt, and a prolonged period of extreme weather which halted operations for many days.

The Author

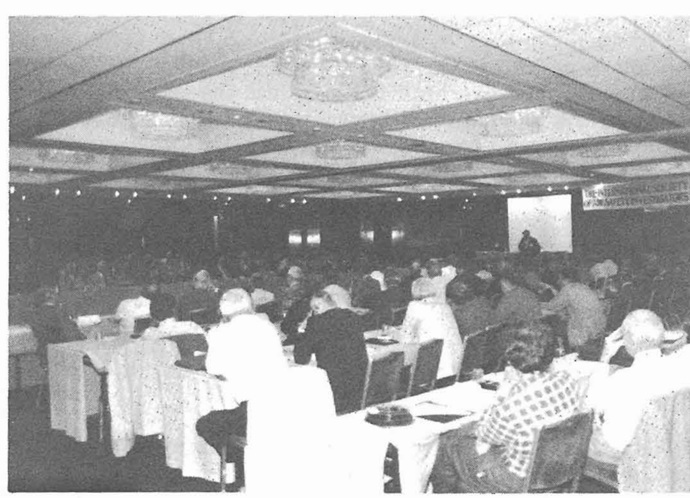
D. F. King

Dave King served a Student Apprenticeship with Hawker Siddeley Aviation, Kingston 1963-70, continuing with HSA in the Future Projects Aerodynamics Department until joining the Accidents Investigation Branch in 1972, since then he has carried out a large number of investigations. Dave has been appointed a Principal Inspector of Accidents. He holds a current Private Pilot's Licence with Instrument Meteorological Conditions Rating.





General Membership meeting



A Case History
The Accident to G-BDAN, a Dan Air B 727, at Tenerife on 25 April 1980

R. G. Matthews
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Royal Aircraft Establishment
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1. Description

G-BDAN took off from Manchester at 0922 hrs bound for the island of Tenerife in the Canary Islands. It had 138 passengers and 8 crew members on board and was expected to land at Tenerife Airport (North) at approximately 1330 hrs.

At 1314 hrs the aircraft, using the callsign Dan Air (DA) 1008, was passed from 'Canaries Area' Air Traffic Control (ATC) to 'Tenerife Approach' and reported at flight level (FL) 110, with 14 nm to run to the VOR[1] 'TFN'. Tenerife ATC then cleared the aircraft "To the 'FP'[2] beacon, via 'TFN', FL 110, expect runway 12 - NO DELAY". The weather at the time was significant only in that the cloud base was 120 metres (400 feet) and there was drizzle.

At this time the controller was apparently unaware of the conflict between a 'domestic' Fokker Friendship which had already entered the approach pattern and the DA 727 flying at nearly twice its speed.

DA 1009 reported having "just passed the 'TFN' and heading to the FP" at 1319 hrs. This position report had been delayed by other radio traffic until 33 seconds after the aircraft had passed 'TFN', leaving only 47 seconds to run to overhead 'FP'.

Immediately following the transmission ATC, suddenly realising that the DA aircraft was rapidly closing with the Iberia aircraft, notified DA 1008 of an arbitrary holding pattern at 'FP', using the words "Roger, the standard holding overhead 'FP' is inbound heading 150, turn to the left, call you back shortly". There was no pattern either authorised or published for holding at 'FP'. The crew were plainly confused by this message but, nevertheless, did not request clarification but proceeded to overhead 'FP'. In fact the flight had never achieved the published outbound track from 'TFN' and consequently passed some 1.5 nm south of 'FP' when reporting overhead. As it did so, ATC cleared the flight down to 5000 feet.

Following a discussion about the holding pattern, the commander said "I'll just turn straight round left onto 150 when I go overhead then". He did this and it was not until the aircraft had turned through some 85°, onto a heading of 179°M, that he questioned his own interpretation of the instruction with the words "Hey, did he say it was 150 INBOUND?".

By this time the aircraft, descending from 6000 to 5000 feet, was about 4 nm southwest of the airfield and in an area notified as having a minimum safe altitude of 14,500 feet. Although the discussion in the cockpit made reference to the proximity of high ground, there was no mention of the safety height.

When the commander realised that he had turned in the wrong direction and was heading towards an OUTBOUND track of 150°M, he rolled off the left bank and was initiating a right turn when the Ground Proximity Warning System (GPWS) sounded. He immediately applied full throttle and pitched up the flight deck angle but unfortunately allowed the aircraft to continue rolling to nearly 40° of right bank. As a result of the bank, the aircraft did not climb but merely slowed the rate of descent. The GPWS warning ceased: not because of the pilot action taken, but because the aircraft had just cleared one mountain ridge and was not flying across a valley. The system had insufficient time to re-arm itself before the aircraft met the next ridge.

The aircraft struck the ground 38 metres (125 feet) below the summit of a 1690 metre (5544 feet) ridge. There were no survivors.

2. Discussion

The severity of the aircraft destruction and the lack of witnesses made the onboard and ATC tape recordings the major source of evidence. Examination of the wreckage and this evidence clearly showed that the accident was caused by 'Human Factors', rather than aircraft malfunction. There were clearly two primary sources of factors leading to the accident.

(a) Crew performance

The fluctuating speeds, lack of precise navigation and 'back-up' by the crew, showed that the flight was not conducted in the professional manner normally shown by the operating company. Precisely, three events were directly contributory to the eventual accident:

(i) Failure of the crew to request clarification of the holding pattern issued.

(ii) Acceptance, by the crew, to follow apparent instructions which directed them into an area where they were flying, in cloud, at a height considerably lower than the minimum safe altitude. Or, geographical disorientation denying to them the knowledge that they were doing it.

(iii) Spatial disorientation, allowing the commander to apply bank whilst reacting to a GPWS warning.

(b) Air Traffic Control

The ATC input to this accident all stemmed from one event: Failure to appreciate the speed difference between the Domestic aircraft (F 27) and the B 727. This was made more difficult by the erratic and unusually high speeds flown by DA1008. However, from this point on, the errors compounded themselves and resulted in the following factors contributing to the accident.

(i) The holding pattern information from ATC did not comprise an executive order to hold.

(ii) The ATC transmission was ambiguous in that the words "Standard Hold", unless otherwise specified in aeronautical documents, means a RIGHT HAND pattern. Therefore "turn to the left" was taken as an executive command rather than (unnecessary) further description of the pattern.

(iii) The given holding pattern was not published and the last holding facility had already been overflown. The 47 seconds remaining was therefore, particularly in view of the unlikely orientation, inadequate to assimilate the unexpected information.

(iv) The pattern was orientated in such a way as to make it very difficult to enter and impossible to leave directly into the approach pattern.

(v) The United Kingdom interpretation of the criteria detailed in ICAO document 8168 results in a minimum safe altitude for the procedural entry into the unpublished holding pattern at FP of 7000 feet and for the pattern itself of 6000 feet. Neither of these two figures includes the recommended extra 1000 feet applicable because of the wind effect in hilly terrain. No evidence came to light during the investigation that, prior to the accident, any minimum safe altitude calculations had been carried out by a competent authority for this entry and holding pattern.

It is worthy of comment that if these criteria had been observed, the controller would not have cleared the aircraft down to 5000 feet and the aircraft would therefore not have flown into that mountain.

3. Conclusion

The two causes of the accident, in chronological order are:

(a) The information about an unauthorised, unpublished and unsafe holding pattern was unexpectedly and ambiguously presented to the crew too late to be assimilated and performed.

(b) The lack of airmanship displayed by the crew when flying at 5000 feet, in cloud, in an area clearly published as having a safety height of 14,500 feet.

The Author

R. G. Matthew

Gordon Matthew began flying in 1954 with the University of Liverpool Air Squadron. Joined the Royal Air Force in 1957 and Transport Command in 1959. His 12 year commission terminated with 2 years of the Far East VIP Squadron in Singapore. Joined Laker Airways in January 1970 and having served for 2½ years as Senior Pilot of the Berlin Station ceased professional flying in 1979 because of medical problems. Joined AIB 12 March 1979. Amongst other public transport accidents, was the UK Accredited Representative to the Spanish Commission of Inquiry into the Dan Air B727 accident at Tenerife on 25 July 1980.

References

1 The radio beacon identified as 'TFN' is of the type known as Very High Frequency Omni Range (VOR)

2 'FP' beacon is of the 'Non Directional Beacon' (NDB) variety

Resources
Follow-Up Action for Accident Prevention

John Knight
UK Civil Aviation Authority

It is often asked after causes of aircraft accidents have been discovered, "Why didn't the regulations prevent it? Why was a defect not found in the man or machine before it became catastrophic?" They are questions that come easily from everyone, from the investigators, the press and the general public. The answers are not always so easy to find. Apart from the legal requirement to do so and for the benefit of potential litigants there is no purpose in carrying out investigations if we do not profit from their findings in terms of reducing the number of accidents.

The United Kingdom Civil Aviation Authority like most other Aviation Authorities worldwide is charged with ensuring that civil aviation both public transport & private is conducted with equipment and in such a manner that an acceptable level of safety is maintained.

If we take the equipment—the aircraft—two main elements of airworthiness control are necessary if that aim is to be achieved

1. Certification of aircraft designed to the relevant Requirements
2. Post certification continued airworthiness.

Certification Requirements are not a designers' handbook stating how an aircraft is to be designed but a minimum standard to which compliance must be shown in order than an acceptable standard of airworthiness may be achieved. If we study the evolution of these Requirements over the years it is clear that we have all been on the learning curve for many decades having to adjust to advancing technologies which have made it possible to fly faster and higher than ever before. Experience, sometimes bitter, has shown that we have not always accurately foreseen in the formulation of these requirements the demand that woulld be placed on both men and machine. Setbacks over the years such as fatigue induced explosive decompression, "T" tail deep stalls and high altitude jet upset were all "phenomena" that were not caught by the requirements at the design stage.

Having now progressed to the stage where the majority of the world's large passenger transport aircraft designed to current requirements are turbine powered, they are of conventional structural design and cruise at 30-40,000" at .85 - .9M. We now have a machine which I believe approaches the optimum in design when considering airframe and power plant integrity. Having said this the world wide accident statistics for passenger transport aircraft, however presented, show that the accident/fatality rate has also reached a plateau. I am not going to attempt to analyse the statistics that we all see and hear quoted so often, but it has to be accepted that there is a price to pay in terms of loss of men and machinery in any transportation activity. If that is so it must be our aim to reduce that price to the absolute minimum. Design requirements while being essential as a starting point will never in themselves guarantee a zero accident/fatality situation anymore than laws on the statute book in themselves stop crime. I think that we would be deluding ourselves if we thought that constantly rewriting the requirements in response to investigation findings will by itself improve the situation.

The safety net that we all have is to inform, analyse and act when we are aware of events which may compromise safety. This applies to all manufacturers, operators, investigators and regulators alike. As most of you probably know the UK CAA launched its Mandatory Occurrence Reporting System in 1976. The motivation for requiring such a system was that there was evidence that information having a bearing on the continued airworthiness of aircraft or on their operating safety was not being disseminated among those who had collective responsibility for ensuring that corrective action was taken. While it is now the responsibility of the CAA to analyse data received and take action as required it does not relieve the individual or reporting body from taking whatever corrective action that may be required in cooperation with the CAA, but it is essential that the matter be reported.

It may be that the course of action that he sees as the correct one for his operation may not be suitable for other operators who may be experiencing a similar problem, or who may not even be aware that a potential problem exists. It is for the Authority to determine, with the benefit of knowledge gained from a much greater catchment area than may be available to the individual operator, what action should ultimately be taken. This approach allows a standard solution to be adopted taking all variables into account and allows an international exchange to take place as part of the decision making process.

There are occasions when information is received concerning an occurrence that when viewed in isolation would appear not to represent a hazard but when examined in combination with earlier information, probably from a completely different source, causes an alternative view to be taken when considering the need for preventative action.

At the end of a three day seminar I am not going to bore you with strings of statistics but I think it is worth stating that since the CAA MOR system started in January 1976, information has been received from world wide sources that have resulted in 32,800 occurrences being recorded of which 7,300 resulted in remedial action taken by CAA. 845 of these were airworthiness related with 143 additional CAA Airworthiness Directives and 93 Alert Notifications being issued. It is not possible to measure the success that those figures represent in terms of how many potential accidents were prevented but if design requirements provide in the long term for the certification of aircraft that will have a declared standard of airworthiness in the first place so it must be that to follow-up with corrective action or incident is a necessary and natural short term reaction, and is therefore clearly of value.

Although we talk formally of MOR (mandatory occurrence reporting) our policy is to encourage reporting across the whole spectrum of U.K. civil aviation. The legal requirements for MOR are of course part of this activity but our procedures for processing reports do not differentiate between mandatory and voluntary. Even before MOR the CAA and its predecessor the ARB were operating an occurrence reporting system but on a relatively informal basis with the obvious pitfalls that this involves.

As I said earlier it is not possible to measure the success of the present system in terms of accidents that were prevented, but benefits of a more general nature which contribute collectively to improvement of flight safety are to be seen. The introduction of MOR has resulted in the Authority setting up more professional procedures for receipt and evaluation of reports with the relevant staff being more accountable for their analysis and subsequent activity. The unified approach that has been adopted, where one system embraces airworthiness and operational occurrences, has resulted in a much closer integration between all divisions of the CAA on safety matters and we believe to some extent has improved liaison between the operations and engineering departments of UK operators.

For those of you who may not be aware of what is produced by the Authority as a result of having received the information, a weekly digest of occurrences concerning public transport aircraft selected on the basis of having a useful safety message for others is published and an equivalent publication—General Aviation Safety Information Leaflet, G.A.S.I.L.—is produced which is available for all those engaged in the nonpublic transport field.

There is now, after eight years, a comprehensive computerized data storage and acquisition facility which provides a data bank which enables information to be retrieved both quickly and accurately both in VDU and print-out form for the benefit of those making technical decisions or investigations within the CAA or industry.

At the time of introduction of the system there was much apprehension within industry that the system would be another regulatory function that would be a further drain on airline and industry manpower and financial resources. After eight years of operation I think that these fears have been allayed and there is evidence that there is now widespread acceptance that the Authority is trying to run a practical system with improved safety as the sole aim. It is a trait of human nature that critics usually outnumber those who are willing to give their commitment to an endeavour such as this, and while constructive criticism is always welcome active support is also required if the declared aim is to be fulfilled. The acquiring and use of safety related data of this sort is the subject of constant development by all countries with significant civil aviation involvement. The success of the international exchange of information depends in the first place on effective national internal reporting system.

For those of you who may not be conversant with the responsibilities of AIB and CAA in this country concerning accident investigation, it is the responsibility of the AIB to investigate an accident fitting the definition of being "reportable" and it is for the CAA to consider what action if any should be taken in response to recommendations that the AIB may make.

Clearly the two bodies do not live in vacuums nor could they afford to do so in the context of their respective involvement in the post accident period. The investigation plays an important part in the regulation of air safety. Crudely put, the accident site may contain the raw material from which improved requirements will grow in the long term, to evidence which shows that immediate precautionary action is required that may only relate to that specific aircraft type. While it is required that the investigation is carried out independently and should be seen to be so, experience has shown that that requirement is not infringed by maintaining good and effective communication links with AIB throughout the course of the investigation. I have reason to believe that this function gives valued assistance to the accident investigation process but the main objective is to provide an essential information link to ensure that the Authority is adequately and promptly briefed on all matters of significance arising from the investigation.

The task of accident prevention is one that requires an input from many sources. The follow-up action activity conducted by the CAA for the prevention of accidents is only one element of the overall goal that we all strive to achieve. Nevertheless it is a resource in financial terms, indeed it is costing the aviation industry of the UK—both manufacturers and operators approximately 600,000 pounds sterling per year, based on 1983/84 figures. If by dedication to this most demanding task we can avoid the loss of one life or prevent one accident I believe that it is money well spent.

Note: The following publications containing information on occurrences are currently available from SDAU:

1. Occurrence Digest
2. New Reportable Occurrences
3. Occurrence Summary
4. General Aviation Safety Information
5. Good Airmanship Guide
6. Explanation of ORS—Publications

The Author

John Knight

John Knight is the Accident Liaison Surveyor in the Safety Data and Analysis Unit of the CAA. John served an apprenticeship in aircraft design and production. He then became a design engineer with the British Aircraft Corporation followed by eight years' service as Air Safety Investigator for the Corporation (now British Aerospace). He has since served for 11 years with the CAA with a particular responsibility for accident follow-up.

John is a Chartered Engineer and a Member of the Institute of Mechanical Engineers.

Memory for a Staged Incident

Mr. D. J. Mingay, Mr. J. L. Dennett
and Dr. D. A. Bekerian
Applied Psychology Unit, Cambridge, England

Introduction

The testimony of an individual who witnesses an aircraft crash can be of considerable use to an accident investigator in trying to determine the cause of the accident. Psychological research suggests that the completeness and accuracy of an account is greatly influenced by the nature of the questions asked. Unfortunately, these studies have focused on the error-proneness of witnesses. Consequently, relatively little is known about which questioning procedure can facilitate a witness's recall most effectively.

One procedure sometimes used by accident investigators is to question a witness about events in the order in which those events occurred. The witness may be better able to remember certain events if reminded or cued by earlier events. In addition, asking questions in the order in which an event occurred may assist a witness to more vividly imagine the events, and this may also lead to better recall.[1]

An alternative procedure involves asking the witness about the final events first. The investigator is usually interested in the behaviour of the aircraft prior to the crash. To the witness, the crash itself is likely to be far more salient. Just after seeing the crash, he or she is likely to think back to the earlier actions of the aircraft to try to decide what caused the accident. If the witness is first asked about the crash, and then about the earlier events, a better account might be obtained, insofar as this procedure parallels the way the witness might have tried to remember the earlier events in question.

In the absence of relevant research, an experiment was designed to compare the relative effectiveness of these two alternative questioning procedures. A "theft" of an overhead projector was staged in front of accident investigators attending the 1984 ISASI conference at Heathrow, England. Most of the incident was quite mundane so delegates were unlikely to have paid much attention to it. This is somewhat analogous to the lack of attention witnesses often pay to an aircraft prior to the crash occurring. The final part of the incident was somewhat more salient: the "thieves" took the equipment out through some fire doors, and a few moments later the sound of a car engine and horn was heard. Twenty minutes later delegates were informed that the removal of the overhead projector had been staged, and asked to complete one of two versions of a questionnaire probing their recall of the appearance and actions of the "thieves."

Methods

The Incident

About thirty minutes prior to the incident, the female "thief" walked into the conference hall holding a clipboard and sat on a chair (position 1, Figure 1). During a short interval between papers, whilst the next speaker was preparing to begin, the male "thief" entered the hall and joined the woman. Both then walked ot an overhead projector on a small table at the front of the hall (position 2). The woman looked closely at it and wrote something on her clipboard. The man unplugged the overhead projector, gathered up the cable and lifted up the machine. Both "thieves" then walked to the fire exit (position 3). The woman opened the door and the man left the hall with the overhead projector. A few moments later, a car engine and horn could be heard. The woman then also left the hall via the fire exit. The whole incident lasted one and a half minutes.

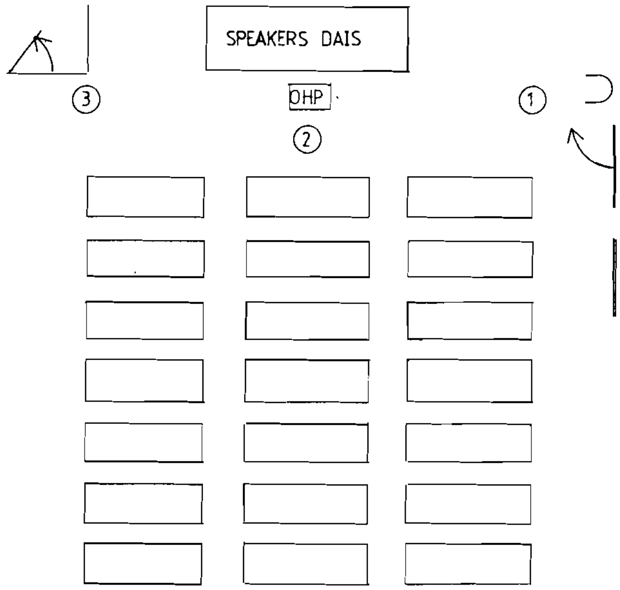


Figure 1

Shortly afterwards, the speaker who had been at the front of the hall began talking. Twenty minutes after the incident had been completed, he was interrupted by the experimenter. She explained to the delegates that the incident had been staged, and asked everyone a questionnaire concerning what had occurred. All delegates present were handed a copy of the questionnaire, the versions being alternated so that no two delegates sitting together would have received the same version of the questionnaire.

Results and Discussion

Of the delegates present in the hall, 108 filled in the questionnaire. Of these, 25% responded "Don't know" to all questions on the questionnaire and were not included in the analysis. This suggets that little attention was paid to the incident, despite the fact that it was the only activity occurring in front of the speaker's dais.

Table 1 presents the results of primary interest, namely those of question order. As can be seen, asking questions in

		ORDER OF QUESTIONING	
		Forwards	Backwards
	Beginning (set a)	30.0 ↓	38.1 ↑
PART OF INCIDENT	Middle (set b)	60.8 ↓	50.6 ↑
	End (set c)	57.9	57.6

Table 1

Arrows indicate the order in which the questions were asked. Percentages of correct anwers in each block of questions, analysed by the order in which questions were asked.

the order in which the events occurred (i.e., forward question order) led to significantly better memory of events occurring in the middle section of the incident (set b). In contrast, asking questions in a backward order (i.e., backward question order) resulted in a significantly better memory for events which occurred in the beginning of the incident (set a). Memory for events occurring at the end of the incident (set c) were unaffected by question order and were always better than memory for events from the other two sets.

It is likely that memory for events occurring at the end of the incident was superior because these events probably received more attention: for example, these events, consisting of the overhead projector being taken out through fire doors and audible noises being heard from outside, were seen as somewhat odd by many delegates and may have, therefore, attracted more attention. Consequently, because greater attention had been given, memory for these events would be expected to be superior, irrespective of how questions were asked.

However, it remains to be explained as to why the different question orders produced superior memory for different parts of the incident. It might be the case that middle events were remembered better with forward order because the forward order reinstated the logical sequence of events as they had occurred: that is, presenting questions qbout the beginning of the incident first may have primed recall of those events that occurred immediately subsequently, namely events occurring in the middle of the incident. The backward order failed to reinstate the logical sequence of events as they had occurred, and therefore failed to provide any relevant cues for events occurring in the middle of the incident.

In contract, the backward order produced superior recall for events occurring at the beginning of the incident. A likely explanation for this effect is that the individual was more likely to rehearse events that occurred at the beginning of the incident whilst attempting to answer questions about other events. Of course, in the forward order, beginning events were asked about first, so that no additional rehearsal would be possible.

It is also worth mentioning that there was no tendency for delegates to better remember the part of the incident which they were best-placed to observe. This suggests that a witness who may have been ideally placed to see an accident will not necessarily be more accurate than another who was less well-placed.

Memory for the appearance of the "thieves" was unaffected by the question order. This result is not really surprising: all individuals received questions about the "thieves" appearance at the end of the questionnaire so that there was ample opportunity for recollection at any point prior to actually answering these questions. What is surprising, however, is the performance on these questions. Table 2 presents the relevant data. It should be noted that judgements of the male "thief's" age, height and hair colour were particularly inaccurate. Fifty-three percent of the delegates estimated the man to be under the age of 35; the man's true age is 50. Only 10% correctly reported that his hair was grey. Accuracy of the descriptions of the man's clothes were also extremely low, averaging less than 7%. Performance on the female "thief's" appearance was more accurate, in general, probably due to the fact that a young, attractive female would receive slightly more attention from a hall filled with predominantly male delegates.

The results obviously permit only tentative suggestions regarding the interviewing of witnesses. For example, it could be argued that there are too many differences between wit-

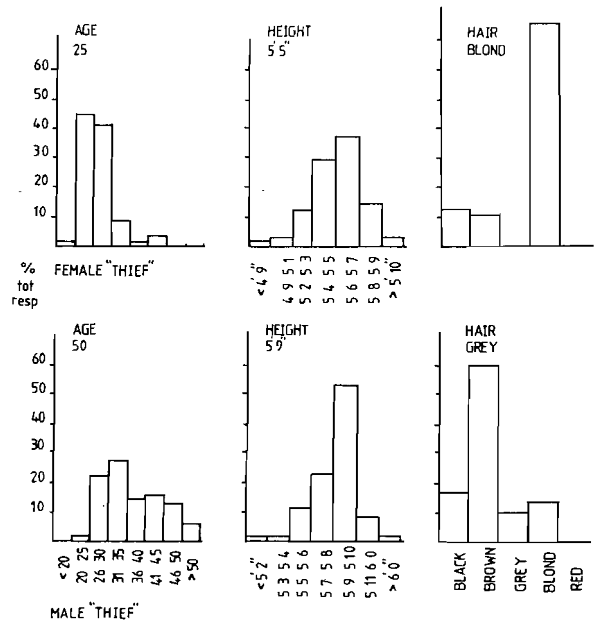


Table 2

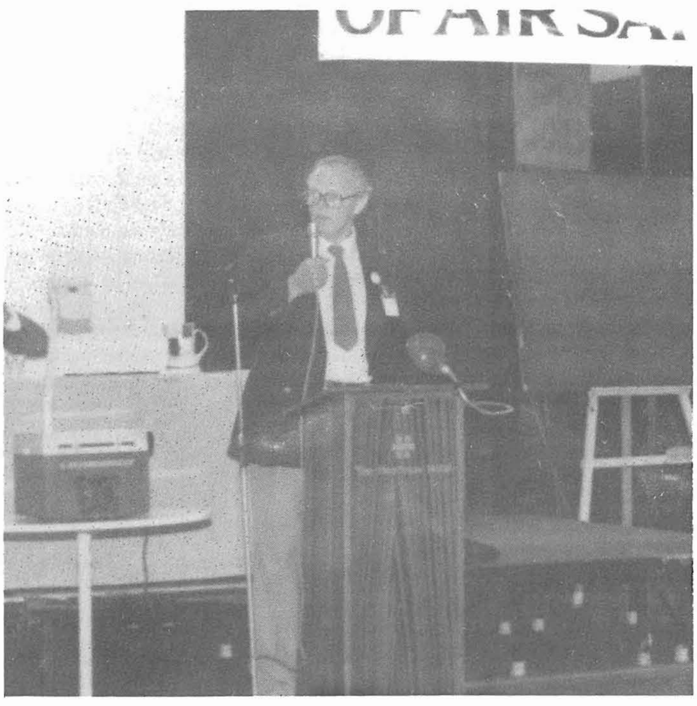
nessing an aircraft crash and witnessing a staged theft to draw any conclusions. However, the results do clearly suggest that memory can be enhanced by question order; and, it seems reasonable to anticipate that memory for other incidents can also be facilitated by particular question orders, especially if the incidents in question are ones that do not necessarily "grab" the witness' immediate attention. For example, an accident investigator might elicit a better account if he asks about relatively unimportant parts of an incident before focussing on those aspects which were more salient and of greatest interest, stressing the logical order of the events in his questioning procedure. In contrast, if the investigator considers what was initially seen by the witness to be the information of greatest importance, he should consider asking questions in a reverse order, beginning with the witness' final sighting of the plane.

Reference

1. Bekerian, D. A., and Bowers, J. M.; "Eyewitness Testimony: Were we misled?" *Journal of Experimental Psychology: Learning, Memory and Cognition,* 1983, *9,* 139-145.

Debate shots

Capt. Dick Stone



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